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Temperature control of heating pads with liquid working medium

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NOMENCLATURE

A_f	area of orifice (developed model)	[m^2]
b_1	parameter 1 of the modified sliding surface	[1/°C]
b_2	parameter 2 of the modified sliding surface	[-]
b_3	parameter 3 of the modified sliding surface	[s/°C]
E_C	accumulated energy consumption	[J]
J_{EQ}	integral criterion considering energy consumption and control quality characteristics	[-]
J_Q	integral criterion accounting only for the quality characteristics of control	[-]
$J_{\varepsilon max}$	cost function used for identification	[%]
k	number of measured data	[-]
p_j	parameters	[-]
PV	process value	[°C]
r	radius of valve bore	[m]
R	radius of valve ball	[m]
s	sliding surface	[-]
SP	setpoint	[°C]
$\check{y}$	measured data	[°C]
$\hat{y}$	simulated data	[°C]
ε	control error	[°C]
τ	time	[s, h]
τ_0	starting time interval used for identification / optimization	[s]
τ_1	ending time interval used for identification / optimization	[s]
φ	rotation of the ball valve	[°]
ω_1	weight factor 1 of the new criterion function	[1/Js]
ω_2	weight factor 2 of the new criterion function	[1/°C^2s]

1. INTRODUCTION, GOALS

In this chapter I will articulate the significance and relevance of the topic and present the objectives of my work.

1.1. Timeliness and significance of the topic

Producing a sufficient quantity of high-quality meat is extremely important today. As a result, animal husbandry must operate on an industrial scale. Production needs to be carried out in an energy-efficient manner while also considering animal welfare guidelines.

One of the most energy-intensive aspects of pig farming is heating, which accounts for a significant portion of production costs and has a notable environmental impact. Given the European Union's new energy efficiency target, which aims for a 32.5% energy saving for the EU by 2030 compared to the 1990 reference value, it is crucial to research energy-efficient heating solutions. Furthermore, according to the current 39/2018. (XII. 13.) AM decree, as amended in 2023, the conditions for receiving animal welfare support, as stated in Section 5, Paragraph 1, Points c) and e), include providing the necessary conditions to prevent fighting and biting and ensuring the creation of a suitable microclimate.

1.2. Objectives

The aim of this research is to examine control algorithms capable of ensuring high-quality and energy-efficient temperature control for systems with large time constants, as well as to further develop the methods for this field and to determine their limitations.

My goal is to build a small-scale model of a system that uses liquid-medium contact heating plates in piglet rearing, connected to a thermal solar energy-based heating booster. Based on measurements taken on this model, I will create mathematical models and thus a validated simulation framework. This framework will allow for the examination of different control algorithms (on-off, PID, sliding mode, modified sliding mode) and various actuators (pump, throttle valve).

This simulation framework can be used to help design real-world systems.

The research can be broken down into the following sub-tasks:

1. Construct a small-scale model of the system under investigation.

2. Develop mathematical models for the system components.
3. Create a block-oriented simulation framework based on mathematical models.
4. Define and integrate control algorithms and strategies to be examined into the model.
5. Establish a unified set of criteria for the optimization and qualification of the control algorithms, and based on these criteria, determine the method and objective function for optimization.
6. Optimize the controllers according to the unified criteria.
7. Perform a comprehensive, technology-focused comparison of the control algorithms and strategies.

2. MATERIALS AND METHODS

In this chapter, I will present the experimental methods and tools used to achieve my research goals, including the software programs used for my investigations, as well as the small-scale system created for the experiments and its constituent components.

2.1. Block-oriented modeling

During my work, I'm focusing on the mathematical modeling and simulation of thermal systems used in animal husbandry, for which a simulation software package is essential. Since the Hungarian University of Agriculture and Life Sciences has a campus-wide license for MATLAB+Simulink, I chose this solution.

The system includes the basic components needed to build mathematical models that describe a solar energy-utilization system, most of which are ordinary differential equations. Simulink contains widely used algorithms for their numerical solution, such as Runge–Kutta or Dormand–Prince, making it the perfect choice to achieve the goals set out in this paper.

2.2. Small-scale model

The experimental setup is a two-circuit thermal solar energy utilization system model suitable for Hardware-in-the-Loop (HIL) simulation. It was built to validate mathematical models and to test the control systems used.

I modeled the solar collector using an electric heating unit to precisely control the heat energy input from the collector. I designed the model in a way that allows for further development.

The heat storage tank is an insulated 40-liter polypropylene container. Both the heat storage and heat transfer media are water.

The heating plate was represented by an uninsulated 30-liter polypropylene tank with a heat exchanger, which was separated from the floor by insulation. The heat storage and transfer medium here is also water.

The ball valve used as the control valve is an ARCO ½" KB.

For examining the pressure conditions, I placed pressure gauges on the inlet and outlet sides of the throttle valve integrated into the circuit.

I calibrated the pressure sensor's output with a 1-meter water column and verified it with a calibrated Bourdon-tube manometer.

I used a calibrated axial turbine flow meter with a pulse output to measure the volumetric flow rate in the water circuits.

During the recording of the pressure difference and volumetric flow rate, I used a one-dimensional Kalman filter.

I measured the electrical power consumption with a power meter.

The temperature was measured at multiple points using calibrated temperature sensors.

Fig. 1 shows a schematic diagram of the experimental setup.

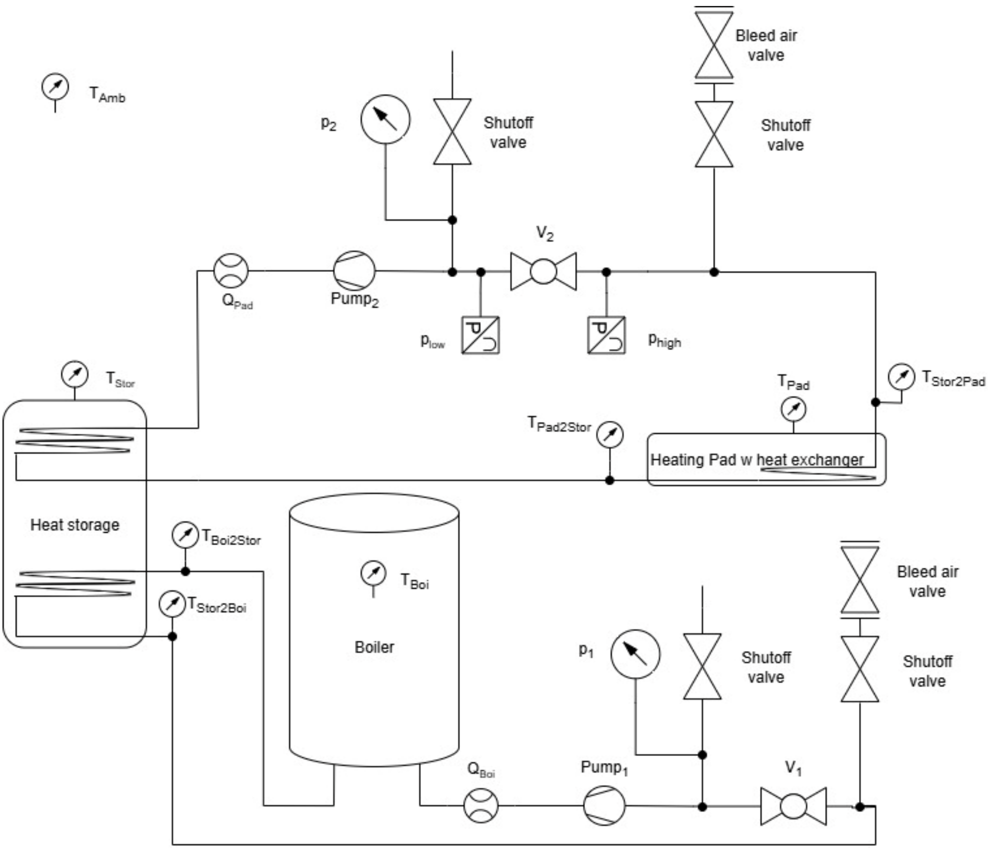

Fig 1. P&ID of the experimental system

2.3. Model identification and validation

After creating the physical models, I subjected them to parameter identification to ensure their behavior accurately approximates reality within 5%. This was achieved using a minimum search algorithm, which optimized one parameter at a time based on an objective function. Although linear regression is used in literature to characterize nonlinear systems, for this work, I used a different approach. Since the industrial standard for heating systems uses a percentage value for temperature deviation, my cost function considers the maximum deviation between the measured and simulated values over the entire measurement period, expressed as a percentage. The cost function is as follows:

$$J_{\varepsilon max}(p_{1,}p_2, \dots, p_j) = \frac{\max\left|\left(\check{y}(k) - \hat{y}(k, p_{1,}p_2, \dots, p_j)\right)\right|}{\max\left|\left(\check{y}(k)\right)\right|} \cdot 100\ ,\%$$

I subject it to a minimum search procedure, where I change the parameters of the examined model in such a way that the value of the objective function is minimized.

$$\min_{p_{1,}p_2,\dots,p_j} J_{\varepsilon max}(p_{1,}p_2, \dots, p_j) \rightarrow\ p_{1,}p_2, \dots, p_j$$

3. RESULTS

In this chapter, I present the results achieved in my research, which aid in the energy-efficient implementation of temperature control for heating plates utilizing a fluid working medium.

3.1. Simulation framework

The simulation framework was specifically designed for the block-oriented modeling of systems that utilize thermal solar energy. The system incorporates mathematical models from the literature that describe the components of a thermal solar energy system. The developed system features open architecture, which allows for the subsequent modification and analysis of models, making it relevant for research and educational applications. Its block-oriented structure facilitates the implementation of flexible simulation procedures. One of the fundamental design goals was to ensure expandability, which includes the integration of new models. In addition to the basic solar energy components, the new framework includes a heat storage model with three heat exchangers, a model for pipe heat loss, a circulating pump model, an improved ball valve model—which enables the simulation of continuous control with this type of actuator—and a heating panel model. The framework also includes several control algorithms used in the industry, a modified sliding mode controller that provides robustness in case of a varying operating point, as well as a complex control algorithm that can realize energy-efficient control by adjusting the pump and throttle valves in a robust manner but without the chattering characteristic of sliding mode control. The elements of the model library are shown in Figs 2-4.

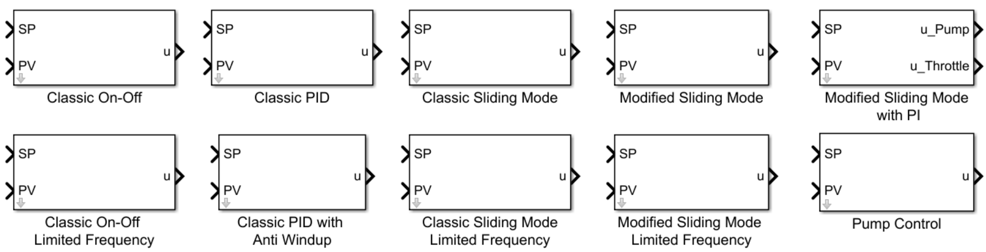

Fig. 2. Controllers of the augmented framework

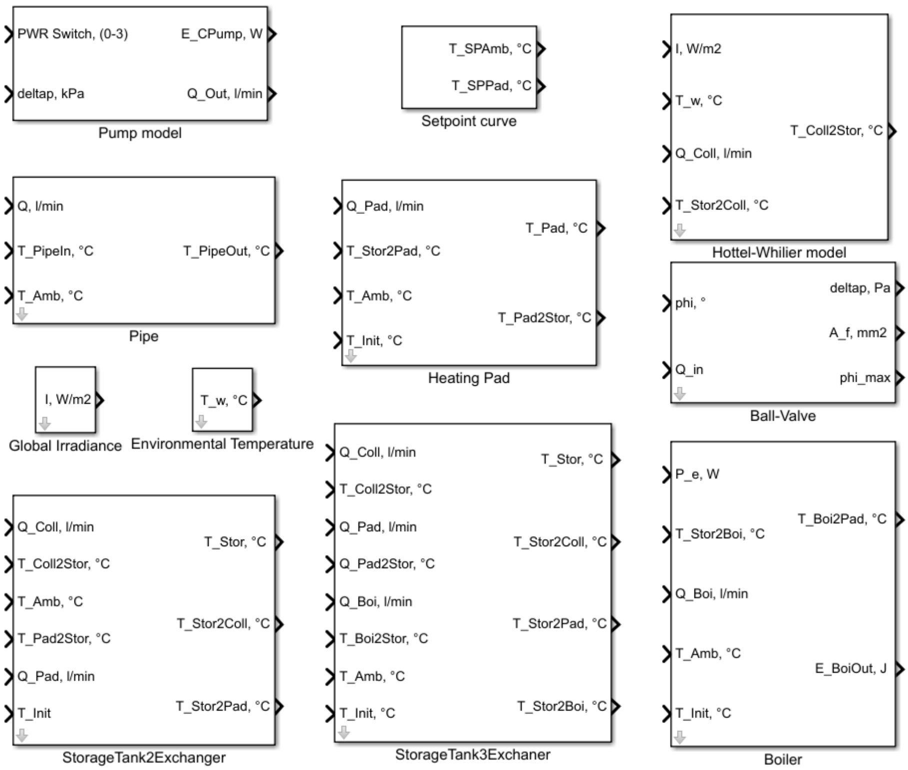

Fig. 3. Model library of the augmented framework

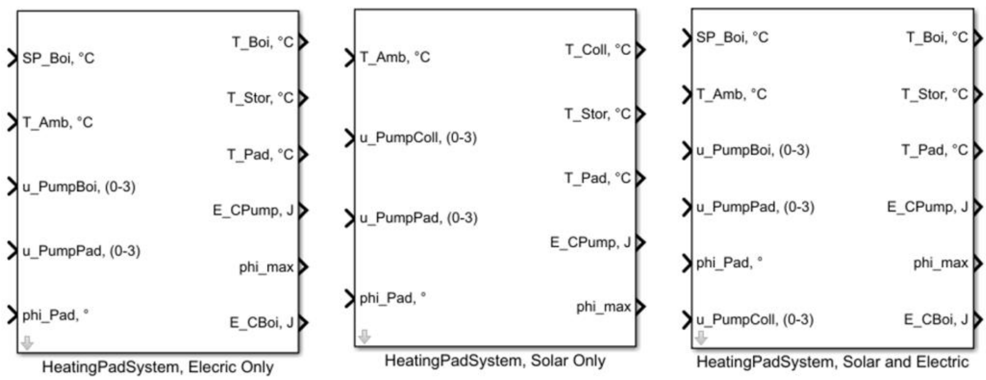

Fig. 4. Models of electrical-only, solar thermal only, and combined systems

3.2. ET throttle model

To enable the retrofitting of old systems, a new and more accurate model for the flow cross-section of ball valves was needed. This model would allow ball valves, which are used as shut-off valves in such systems, to be used as continuous regulators, or quasi-throttle valves. While a model exists in the MATLAB Simscape software package, the *Ball Valve (IL)* block which can be used in isothermal liquid network it approximates the development of the flow cross-section by the area of the overlap between of two circles the valve port and the ball bore. This problem is illustrated in Fig. 5.

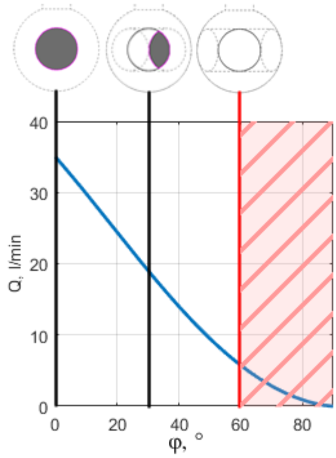

Fig. 5. Inaccuracy of the Simscape model's ball valve volumetric flow rate calculation as a function of the closing element's angular displacement

The newly established ET-model is a geometry-based, white-box model that I validated using CAD software (Fig. 6) and measurements (Fig. 7). The closed-form relationship describing the area of the flow cross-section is as follows:

$$A_f(\varphi, r, R) = -\sqrt{(R^2 - r^2)(r^2 - (R^2 - r^2)\tan^2\frac{\varphi}{2})}\sin\varphi +$$

$$+ r^2(\cos\varphi + 1)\sin^{-1}\left(\sqrt{r^2 - (R^2 - r^2)\tan^2\frac{\varphi}{2}}\right).$$

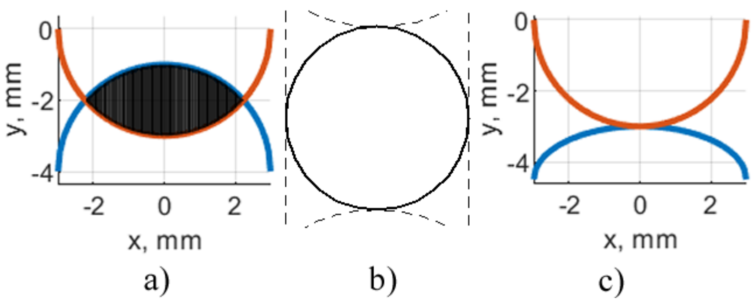

Fig. 6. Comparison of the Simscape model, the CAD model, and the ET-model

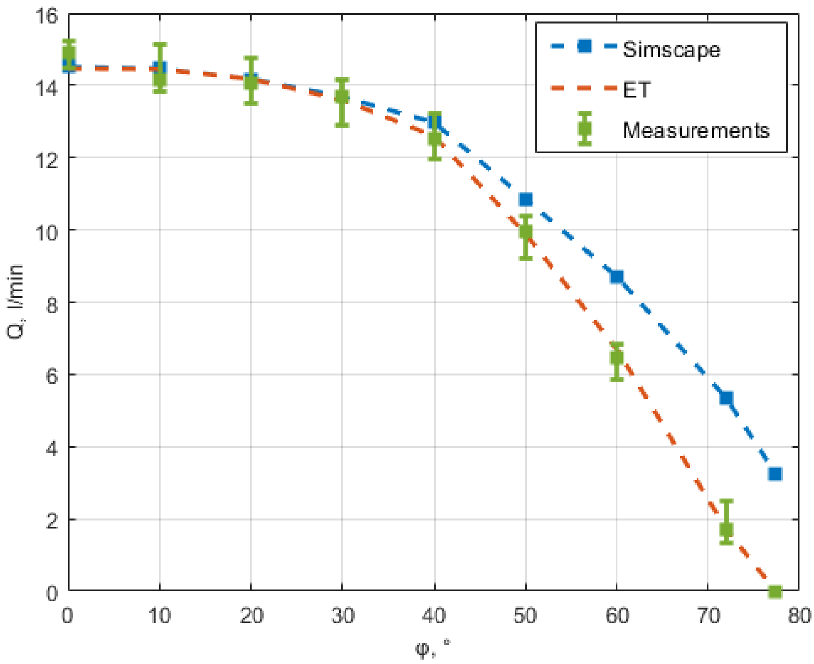

Fig. 7. Comparison of measurement and simulation results

3.3. Objective function for the unified optimization and comparison of control algorithms and strategies

A quantitative value (J_{EQ}) that simultaneously considers the energy consumption and quality characteristics of the controls, which can also be called quality factor. The optimization was performed using the following equation:

$$J_{EQ}(p_{1,}, \dots, p_j) = \omega_1 \int_{\tau_0}^{\tau_1} E_C\,(\tau, p_{1,}, \dots, p_j) d\tau + \omega_2 \int_{\tau_0}^{\tau_1} \left(SP(\tau) - PV(\tau, p_{1,}, \dots, p_j)\right)^2 d\tau.$$

For the sake of comparability, the results of a one-day simulation are presented in Table 1. According to the criteria, the better control system is the one with the lower quantitative indicator.

Table 1. Unified comparison of control algorithms and strategies based on a one-day simulation

Daily, for May 30th of the year			
Controller	Energy consumption, kWh	Quality of control, J_Q	Quality factor, J_{EQ}
On-off, throttle opening/closing	14.32	$8.814 \cdot 10^4$	$2.313 \cdot 10^5$
On-off, turning the pump on or off	12.3	$8.814 \cdot 10^4$	$2.111 \cdot 10^5$
PI throttle	15.08	$4.948 \cdot 10^4$	$2.003 \cdot 10^5$
PI throttle and anti-windup	15.05	$1.499 \cdot 10^4$	$1.655 \cdot 10^5$
Sliding mode throttle	14.29	$1.499 \cdot 10^4$	$1.579 \cdot 10^5$
Sliding mode pump	12.27	$1.499 \cdot 10^4$	$1.377 \cdot 10^5$
Modified sliding mode throttle	14.29	$1.498 \cdot 10^4$	$1.579 \cdot 10^5$
Modified sliding mode pump	12.27	$1.498 \cdot 10^4$	$1.377 \cdot 10^5$
Combined modified sliding mode	**11.98**	$\mathbf{1.528 \cdot 10^4}$	$\mathbf{1.351 \cdot 10^5}$

Based on the data, although the combined modified sliding mode control has a lower quality characteristic (J_Q) compared to all other controllers examined—except for the two-position and anti-windup-free PI controllers—its exceptionally low energy consumption makes it the top choice. In this case, a "worse" quality characteristic means that the steady-state temperature of the heating panel deviates from the setpoint by a value within the resolution of commonly used temperature sensors in practice ($e_{max} = \pm\, 0.075\ °C$), which does not adversely affect the animals' thermal comfort.

Comparing the solar-assisted combined controller with the widely used two-state controller (which has a deviation of $e_{max} = \pm\, 1{,}59\ °C$), we can see a significant difference in the quality of the two controllers. In terms of energy consumption, over one year of operation for a single heating panel, the difference is 629 kWh.

This may not seem like a significant difference at first, but if we consider that, according to Hungarian Central Bureau for Statistics (HCSB) data, 3,248,000 piglets in Hungary spend their first 91 days on the type of heating panels presented here (as they also lie on such panels for the first 35 days in the farrowing unit), it can be calculated that the combined solution, at a national level—even if only one in every hundred piglets uses a heating panel, and it is only used for 182 days a year (since we cannot count the gestation period)—results in an annual savings of 5,093,487 kWh. According to HCSB data, this is equivalent to the annual electricity consumption of 2,300 average households and the emission of 1,782,720 kg of carbon dioxide.

3.4. Modified sliding mode controller

One potential flaw of the classic sliding mode controller can be found in the straightness of the sliding surface. To avoid oscillations, it is sufficient for the derivative of the error (the speed of change in the error) to be high only when the error is large. As the controlled variable approaches the desired value, it is advisable to use a flatter trajectory. This is addressed by the following controller employing a modified sliding function (or modified sliding surface), which, although it is a discrete-time solution, features a low rate of change of the error in the vicinity of the setpoint (Fig. 8).

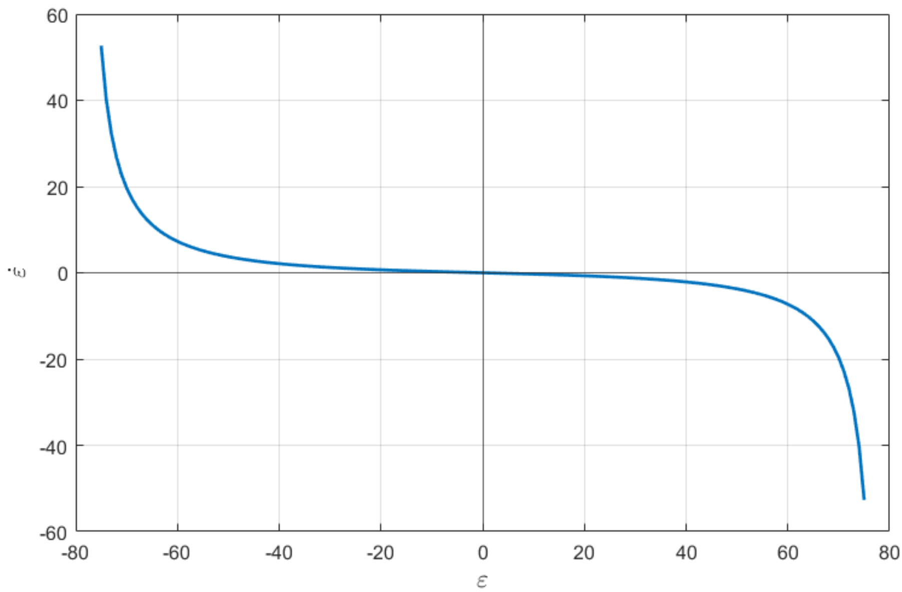

Fig. 8. Sliding function of the modified sliding-mode controller

The equation describing the sliding surface is as follows:

$$s(\tau) = b_1 \frac{\mathrm{d}\varepsilon}{\mathrm{d}\tau} - b_2 \tan(\pi - b_3 \varepsilon(\tau))$$

3.5. Combined modified sliding mode

To achieve the set goal, I investigated several combined control algorithms, thereby creating a chattering-free and energy-efficient control method based on a modified sliding mode controller. The controller is a modified sliding mode – PI cascade solution that actively influences not only the position of the valves belonging to each heating panel but also the performance level of the circulating pump simultaneously. The structure of the controller is illustrated in Fig. 9.

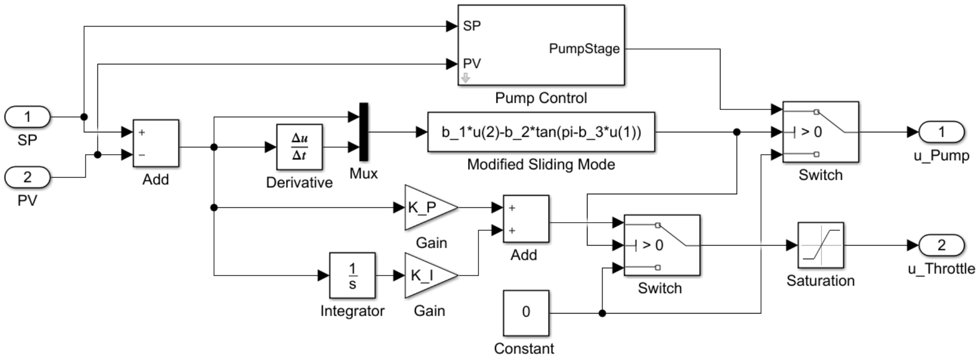

Fig. 9. Structure of the combined modified sliding-mode controller

4. NEW SCIENTIFIC RESULTS

1. Fluid technology and control engineering simulation framework

During the research work, I have created a new, extended simulation block library based on the SimSolar framework. This library is suitable for modeling electric, purely solar, and hybrid systems with a liquid working fluid. The library has been supplemented with new controller models such as the static controller with intervention frequency limitation, the modified sliding-mode controller, the pump power controller, and the combined sliding-mode controllers.

2. Geometric modeling of a throttle valve

I have developed a physics-based model that describes the flow cross-section of a ball valve. The new model considers geometry, specifically the radii of the ball and the bore. The derived relationship, based on this geometry, accurately determines the flow cross-section value across the entire range of the closing element's angular displacement.

The closed-form relationship describing the area of the flow cross-section is as follows:

$$A_f(\varphi, r, R) = -\sqrt{(R^2 - r^2)(r^2 - (R^2 - r^2)\tan^2\frac{\varphi}{2})}\sin\varphi + r^2(\cos\varphi + 1)\sin^{-1}\left(\sqrt{r^2 - (R^2 - r^2)\tan^2\frac{\varphi}{2}}\right),$$

where:

- A_f: area of orifice, m^2,
- φ: rotation of the ball valve, °,
- r: radius of valve bore, m,
- R: radius of valve ball, m.

3. Cost function considering energy efficiency and quality characteristics

I have developed a unified comparison method for the temperature control of heating plates with a liquid working fluid, as well as a cost function suitable for unified optimization. This allows for the comparison of a control system's energy efficiency in addition to its quality characteristics.

The new cost function is:

$$J_{EQ}(p_{1,}, \dots, p_j) = \omega_1 \int_{\tau_0}^{\tau_1} E_C\left(\tau, p_{1,}, \dots, p_j\right) d\tau + \omega_2 \int_{\tau_0}^{\tau_1} \left(SP(\tau) - PV\left(\tau, p_{1,}, \dots, p_j\right)\right)^2 d\tau,$$

where:

- J_{EQ}: integral criterion considering energy consumption and control quality characteristics,
- p_j: parameters, -,
- E_C: accumulated energy consumption, J,
- τ: time, s,
- ω_1: weight factor 1 of the new criterion function, $\frac{1}{\mathrm{Js}}$,
- ω_2: weight factor 2 of the new criterion function, $\frac{1}{{}^\circ\mathrm{C}^2 s}$,
- SP: setpoint, °C,
- PV: process value, °C.

4. Modified sliding mode controller

I have created a modified sliding-mode controller that uses a logarithmic-based function as its sliding surface. The function describing the new sliding surface is:

$$s(\tau) = b_1 \frac{\mathrm{d}\varepsilon}{\mathrm{d}\tau} - b_2 \tan\big(\pi - b_3 \varepsilon(\tau)\big),$$

where:

- s: sliding surface, -,
- τ: time, s,
- ε: control error, °C,
- b_1: parameter 1 of the modified sliding surface, $\frac{\mathrm{s}}{°\mathrm{C}}$,
- b_2: parameter 2 of the modified sliding surface, -,
- b_3: parameter 3 of the modified sliding surface, $\frac{1}{°\mathrm{C}}$.

Using simulation experiments, I have proven that the modified sliding-mode controller I developed for the system under study has a 7.76% better Integral of Time-weighted Squared Error (ITSE) quality characteristic over a one-year examination period compared to a classical controller using a linear sliding surface that was optimized in the same way.

5. Combined algorithm for temperature control of heating plates

I have developed a combined control algorithm and strategy that improves the energy efficiency and control quality of liquid-based heating systems. The method combines the robustness of the modified sliding-mode controller with a proportional-integral (PI) controller and an additional pump power controller. I have demonstrated through simulation experiments that this new type of controller results in an 11.53% energy savings and a 99.6% improvement in the Integral of Time-weighted Squared Error (ITSE) quality characteristic compared to a traditional two-position controller.

I conducted tests on systems with one, ten, and thirty heating plates.

The simulation parameters were as follows:

- One heating plate size: 1200 x 500 x 65 mm, with a volume of 39 liters.
- One solar collector effective area: 1910 x 950 mm.
- For 1, 10, and 30 heating plates, respectively:
    - Electric heating power: 1.8 kW, 12 kW, 24 kW,
    - Heat storage tank volume: 120 L, 1200 L, 2000 L,
    - Number of solar collectors: 4, 10, 50.

5. CONCLUSIONS AND RECOMMENDATIONS

Through my work, I have obtained results related to the temperature control of liquid-medium heating plates in pig farming, supplemented by solar thermal energy utilization, which provides practical assistance in selecting the control algorithms and strategies for such systems.

I built an experimental device suitable for modeling both thermal solar energy utilization systems and traditional heating systems. I conducted measurements on this device, and the results served as the basis for the parameter identification and validation of the new models within the simulation framework. I recommend expanding the experimental system.

By expanding the SimSolar framework, I created a new, comprehensive model library that describes the components of floor heating systems. This library is suitable for time- and cost-effective, model-experiment-based comparison of new control algorithms and strategies. I suggest further expanding this library with mixing valves and functions that describe the pressure drop in pipes.

I developed a physics-based throttle model that can accurately describe the use of ball valves—which are traditionally used as shut-off valves in heating systems—as throttles. I recommend developing models for ball valves with different pipe-bore diameters.

I also developed a new combined control algorithm and strategy that can significantly increase energy efficiency without a significant decline in the quality characteristics of the control. This can contribute to achieving the European Union's energy efficiency goals set for 2030. I recommend testing additional control strategies and algorithms in both the user and energy storage circuits.

I developed a criterion function that allows for the unified comparison of both new and currently used control algorithms and strategies, which has practical significance for selecting the right solutions. I suggest expanding this criterion function with additional parameters, such as the switching frequency, which is important for discrete controllers, and also expanding the hydraulic system with an expansion tank.

6. SUMMARY

The goal of my research was to develop an energy-efficient control algorithm and strategy that considers the climate policy objectives of the European Union as well as the requirements set forth in animal welfare guidelines. Based on my professional background, I focused on optimizing underfloor heating systems, which are widely used in pig farming.

Currently, the heating systems used in animal husbandry typically generate the contact temperature necessary for animal comfort directly from fossil fuels or electricity. Often, the control systems are inaccurate, leading to increased stress in piglets, and in extreme cases, even mortality. Therefore, the task is to find a solution that reduces heating emissions and improves the quality characteristics of the control by utilizing solar thermal energy and enhancing the energy efficiency of the control system.

To achieve this goal, I chose a simulation method recommended by literature. I developed an extensive simulation model package based on the SimSolar framework, which includes models for most of the components used in such systems.

I created a new model based on geometry, describing the ball valve as a throttling device, which allows for the investigation of its application as a continuous regulator in systems where it was previously used solely as a shut-off valve.

To identify parameters and validate the models, I constructed an experimental system on which I conducted several measurements under varying environmental and initial temperature conditions, adhering to the relevant principles set forth in the literature.

I developed several new control algorithms and strategies and compared them with those currently used in the industry. This involved performing model experiments in the extended, validated simulation framework, where I examined multiple control algorithms and strategies, as well as their combinations.

I optimized and ranked the controllers according to a new unified criterion function that I established. I also examined the operating point dependence of the most successful control solutions and, based on these findings, compiled a

unified table characterizing the controllers from various perspectives, which can assist in selecting the appropriate solution for practical implementation.

Finally, I concluded that the new control algorithm I developed could contribute to achieving the European Union's energy-saving targets without compromising the thermal comfort of the animals and, consequently, the production indicators.

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7. NOTABLE PUBLICATIONS RELATED TO THE DISSERTATION'S TOPIC

Refereed scientific article in foreign language

1. **Erdélyi V**., Tóth J., Buzás J., Földi L., Székely L., Farkas I. (2025): New Cross-Section Model for full Bore Ball-Valves, Periodica Polytechnika Mechanical Engineering, IF 1.0, DOI 10.3311/PPme.40915

2. Alshibil A., Víg P., **Erdélyi V.**, Tóth J., Farkas I. (2024): Performance Assessments of Direct Contact Serpentine Tube Based Photovoltaic Thermal Module: An Experimental Comparison, Journal of Engineering and Sustainable Development, Vol. 28, Issue 4., pp. 473-479., ISSN 2520-0925, DOI 10.31272/jeasd.28.4.6, Q3, SJR 0.16

3. **Erdélyi V**., Buzás J., Földi L. (2020): The use of solar thermal systems in piglet nurseries, Mechanical Engineering Letters: R and D: Research and Development, Vol. 20, pp. 73-79.

4. **Erdelyi V.**, Toth J., Janosi L., & Farkas I. (2020). Modelling experiments with small-scale thermal system used for pig fattener heating. In IOP Conference Series: Materials Science and Engineering (Vol. 749, No. 1, p. 012034). IOP Publishing, DOI 10.1088/1757-899X/749/1/012034

5. **Erdélyi V.**, Tóth J., Jánosi L., Farkas, I. (2019): Experimental results of a small-scale thermal system, Mechanical Engineering Letters: R and D: Research and Development, Vol. 18, pp. 7-16.

6. **Erdélyi V.**, Jánosi L., (2019): Digital Twin and Shadow in Smart Pork Fetteners, International Journal of Engineering and Management Sciences / Műszaki és Menedzsment Tudományi Közlemények Vol. 4, Issue 1., pp. 515-520. DOI 10.21791/IJEMS.2019.1.63

7. **Erdélyi V.**, Jánosi L. (2017): Model based optimization in smart livestock farming: an introduction, Mechanical Engineering Letters: R and D: Research and Development, Vol. 15, pp. 164-172.

8. **Erdélyi V.**, Jánosi L. (2015): Agriculture 4.0 or the complex optimization of agricultural tasks based on the experience of industry 4.0, Mechanical Engineering Letters: R and D: Research and Development, Vol. 13, pp. 7-13.

Refereed scientific article in hungarian language

9. **Erdélyi V.**, Földi L., Buzás J. (2021): Folyadék munkaközegű fűtőlapok szabályozása az állatjóléti komfort biztosítására, Energiagazdálkodás Vol. 62, Issue 2-3, pp. 23-27.

10. Tóth J., **Erdélyi V.**, Jánosi L., Farkas I. (2019): Termikus napenergia-hasznosító rendszer kismintamodelljének identifikációja, Magyar Energetika, Vol. 26, Issue 4, pp. 18-23.

International conference proceedings

11. **Erdelyi V.**, Toth J., Janosi L., Farkas I. (2020): Modelling experiments with small-scale thermal system used for pig fattener heating, IOP Conference Series: Materials Science and Engineering, Vol. 749, Paper: 012034, pp. 1-8.

12. **Erdélyi V.**, Jánosi L. (2018): Model based optimization of pork fetteners, Proceedings of the 6th International Scientific Conference on Advances in Mechanical Engineering (ISCAME 2018): Book of extended abstracts, Debrecen, Magyarország: Department of Mechanical Engineering, Faculty of Engineering, University of Debrecen (2018), Vol. 238, pp. 47-48.

13. **Erdélyi V.**, Jánosi L. (2016): Mechatronics in agriculture, CEurSIS 2016: The International Conference of the Carpathian Euro-Region's Specialists in Industrial Systems. 11th Edition – Proceedings, Cluj-Napoca, Románia: Editura U.T. Press, pp. 75-79.

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