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Review report on PhD thesis of Ing. Jiří Dostál

To whom it may concern,

In conformity with the requirements for awarding a Ph.D. degree in the Czech Republic, I, Alexander Schirrer, senior scientist at TU Wien, Institute of Mechanics and Mechatronics, may hereby act as a reviewer of the Ph.D. thesis of Ing. Jiří Dostál entitled "Hydronic Networks: Concept and Control". My account of the thesis content and quality, as well as my recommendation are stated in the following.

In this thesis, a broad treatment of hydronic networks in the building heating domain is given. It elaborates on efficient model structures, main components, and their interrelations in hydronic network systems. Appropriate control approaches and architectures are proposed in this context, clearly showing the benefits of several newly proposed contributions. The thesis is built up in a logically structured manner with a plausible, well-balanced mix of methodological foundation and application problems, covering a broad industrial field in a remarkable breadth and depth.

Relevance of the thesis
The thesis topic is highly relevant given the current global climate crisis and the global need to realize effective measures to combat climate change. As heating energy demand represents a major share of total human energy consumption, scalable efficient concepts to unlock energy savings potential are extremely valuable. The thesis provides a coherent and comprehensive treatment of this domain, both on a methodological and on an application level.

Fulfillment of main objectives; Main results and contributions

The thesis sets out to address four main goals:

Study hydronic heating in buildings. Albeit not a directly measurable goal, a satisfactory overview of hydronic building heating systems is given, and some core components are picked out and highlighted in detail. The author succeeds in presenting a comprehensible and sufficiently detailed account of hydronic heating systems in buildings.

Define control/estimation concept. A comprehensive, powerful concept of hydronic network control and estimation is devised in several variants by applying advanced control theory to the building thermal control domain. Innovative solutions and interesting insights are given at many points throughout the thesis, succeeding in devising a well-thought-out overall concept for networked systems while exploiting the specifics of the hydronic heating application field.

Simulation tool development. A convincing, relevant set of modeling and simulation tools for all involved control and estimation layers has been developed, ranging from system-theoretic analysis tools to a novel and efficient approach to solve 1D hyperbolic advection-dominant plug-flow problems. Furthermore, a hydronic network solver framework is proposed, exploiting the specific characteristics and structures of the associated graph topology. Finally, the concept is outlined at the building control level, and suitable methods for building model co-simulation, calibration and model predictive building control are detailed.

Algorithm development and validation. Innovative control concepts are envisaged and detailed at various levels of the proposed concept. Part II of the thesis on load power control outlines power control valve and power control pump solutions. Furthermore, a remarkable core analysis result is given as a simple sufficient criterion on large-scale network stability which states design bounds for individual SISO loop controllers for two-pipe systems. Finally, as an example, one particular algorithmic contribution in Part III is the adoption of the distributed estimation approach based on dual decomposition for the building model structures.

Summing up, the posed set of goals is appropriate, and they are all achieved in the thesis. The rich results are of high scientific quality (as proven by the high-ranking underlying publications) and cover the domain well. It would have been preferable to also detail the component control concepts' details (which are omitted with the reference to business secrecy), but the reservations of industry interests is understandable and acceptable in these cases.

Appropriateness of the methods

A suitable portfolio of appropriate state-of-the-art methods from system theory, thermodynamics, control theory, and networked systems theory is employed, utilized, and extended throughout the thesis. While the array of methodological tools is broad and fairly advanced, the author manages to clearly explain the methods and make them accessible to the reader in the given context. The excellent text structure and quality help in logically grasping and connecting the concepts, making the proceeding throughout the thesis a well-balanced, plausible, and interesting mix of methods and illustrative results. Hence, the thesis not only achieves the posed objectives in an excellent way but also bears significant tutorial and didactic value for a general engineering audience. This is particularly positive as such the thesis can and should have a high impact and wide reach into the scientific community as discussed above.

Importance for the further development of science

As outlined above, the scientific level of the thesis, backed by high-quality publications, is excellent. The thesis presents highly important results on which the scientific community can build up on. As a particular example, the stability criteria put forward for the considered class of networked hydronic systems is of high methodological value for other researchers, also beyond the field of hydronic applications.

Satisfaction of conditions of a creative scientific work

It is clearly evident throughout the thesis and outlined by appropriate literature references, that the candidate has significantly contributed to and extended further the state of the art in the field of (hydronic) networked system modeling and control. Innovative and creative solutions on the methodological side (efficient flow simulation approaches, stability criteria for networked control) as well as on the application side (as seen by the referred candidate's patents) have been developed by the candidate.

Verdict

The author of the thesis proved to have the ability to perform research and to achieve scientific results of high quality. I do recommend the thesis for presentation with the aim of receiving a Ph.D. degree.

In conclusion, I am honored and kindly thank CVUT Praha and the CVUT Faculty of Electrical Engineering for the invitation to act as a reviewer of this thesis, and I wish Ing. Dostál all the best in concluding his Ph.D. and in his further career!

Kind Regards,

Alexander Schirrer

| Signed by: | Alexander Schirrer |
| Date: | 30.11.2023 09:55:01 |

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