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Refer: Reviewer Assessment of PhD Thesis Eng, Yogender Pal Chandra

Dear Prof. Ing. Tomáš Jirout PhD,

I was appointed as external reviewer for the PhD Thesis of Eng, Yogender Pal Chandra an April 2nd 2024. In the following I give my reviewer´s assessment of the theses. I follow the items mentioned in your letter

- Achievement of the aims of the thesis

The aim of the theses was given with separate the good from the bad operational parameters of TES operation in view of stratification and heat pumps used for charging by the use of second law of thermodynamics models during charge and discharge. Additionally, the parameters should be shown in stream processing to the users.
Assessment: Unfortunately, the work entitled with “Stratification in storage tank for heat pumps” is not reflecting the needs of heat pumps but more the ones of solar thermal systems. Heat pumps produce normally only 5-8°C temperature lift of the heated water in the condenser in order to keep the COP high. Therefor storage connection to the HVAC hydraulics for domestic hot water systems look completely different to the ones presented here. This is also seen in the low COPs achieved. The heat input to the store for heat pumps should be either via internal heat exchanger or via flow/return pair in the lower part of the store and the temperature sensor is slightly above. This assures to start the heating up at low temperature with high COP (when the temperature of the sensor is e.g. below 25°C) and slowly increasing the temperature of the lower part until the temperature equals the upper part and the whole storage is heated up. The high flow and low delta T of heat pumps is mentioned several times in the theses but the store investigated is only working with high Delta T and low flow (which also is a result of the study). Unfortunately, no word is given, how a good storage for heat pumps should look like to yield high SPFs of the heat pump.

For the investigated store a CFD simulation was carried out for different inlet geometries on the cold side for discharging, nothing is simulated with CFD for the charging situation for the situation occurring for heat pumps.
On the other hand the chosen methodology using second law analysis wit mix-number, Richardson number and exergy content is useful (and was developed by many other authors before) to calculate temperature losses and the for the useful energy stored in a tank taking into account the mixing of hot and sold water in a tank. Additionally, the experiments carried out for charging and discharging are needed to calibrate the results. Unfortunately the geometry for the flow inlet for charging the tank is not described.

- Level of analysis of state-of-the art done on the issue dealt with in the dissertation

Assessment: The first paper describes very well the state of the art of heat storage simulation in general, but the specific needs of heat pumps is just shown briefly in 2 figures without explanation why the HP inlets and outlets are chosen in this way. In the 2nd paper the state of the art of CFD analysis hot water storage is described fine. The other papers deal with the machine learning based prediction of measurements for a specific storage design. Also here the state of the art is described quite well.

- Contribution of Ph.D. thesis to the theory of the subject elaborated

Assessment: The contribution to the theory of the subject is limited to the prediction method of tests already performed by machine learning and the only visualization of 2nd law analysis during testing of storages.

- Contribution of Ph.D. thesis to engineering practice

Assessment: For engineering practice, the results of the CFD analysis of different inlet tube configurations for discharging is helpful. Unfortunately, the height of the inlet was not varied, which significantly will change the stratification (the lower the inlet the better). I doubt that the second law analysis is relevant for engineering practice.

- Relevance of applied methods

Assessment: The method of CFD calculation (2nd paper) for water storage tanks is not very new but gives reliable results for specific situations. Of course, measurement tests must be conducted to calibrate the inputs of the simulation. Because of the high computational effort CFD is not useful for seasonal calculations an e.g. hourly or 5 minutes time step. Here 1-dimensional models (fixed layer od plug flow) are used in commercial and scientific tools. Unfortunately, the thesis does not compare the results of the measurements and the CFD situations to one if these simpler tools to explain the advantage of CFD for such specific questions or discuss the difference of both simulation concepts on a seasonal basis.
The machine learning concept shown in the other 3 papers is just repeating the measurements done without any possibility for predictions out of the measured range. The learning effect is – what will happen if I do very similar things again. If all possible situations that will occur during a season have machine learning models behind, there may be a better simulation output also on a seasonal base.

But such considerations are not given in the thesis. So, to my opinion, the relevance of such machine learning algorithms is quite small for further projections and extrapolations.
Machine learning results are not compared to the CFD results.

- Relevance and approach to the method application

Assessment: The thesis is using the methods without critical reflection, whether the methods are appropriate and whether other methods will yield similar results.

- Adequacy of student´s knowledge in special field as demonstrated by the dissertation contents

Assessment: Within the field of CFD simulations and especially machine learning the student has a high competence. Nevertheless, the connection to the real problems of heat pump hydraulics and incorporation of heat storage in the system is mostly missing.

- Formal Issues of the Ph.D thesis

Paper 3-5 are very similar and have large identical passages. To me it is not clear, why they have been accepted as different papers. Figures are not always explained sufficiently and partly the nomenclature is not complete. Pumps are missing in hydraulic schemes. Details of inlet tubes for charging are not described.
Of course, the papers have been refereed already and it is not my task to judge on the refereeing process.

- Explicit statement whether you recommend or do not recommend the dissertation to the final defense presentation

As the formal needs for the PH.D: theses are fulfilled I recommend this dissertation for final defense. Nevertheless, the connection to heat pumps should be discussed in the defense and the title of the thesis may be changed.

Best regards

Wolfgang Streicher