Technical University of Denmark

Popular science summary of the PhD thesis

PhD student	José Joaquín Aguilera Prado
Title of the PhD thesis	Digital twin-based services for large-scale heat pump systems
PhD school/Department	DTU Construct

Science summary

Large-scale heat pumps are a promising technology for heat production, enabling the integration of energy systems, the use of renewable energy, and the recovery of excess heat. Unlike household heat pumps, large-scale heat pumps have higher complexity and reliability requirements. To ensure their performance and availability are as expected, it is crucial to develop dedicated monitoring and maintenance services. Digital twins, which are virtual representations of physical systems, offer the possibility to outperform conventional monitoring and control strategies. However, their use in the heat pump industry is currently limited.

This thesis investigated digital twin-based services to ensure the reliable and efficient operation of large-scale heat pump systems. First, common operational challenges in these systems were identified, with fouling and refrigerant leakage being the most frequent faults. Secondly, a monitoring framework using digital twins was developed and implemented for a large-scale heat pump system affected by fouling. This framework used simulation models that were repeatedly adjusted online based on measured data, enhancing the accuracy of the models and enabling the characterization and mitigation of fouling. Thirdly, the previously developed monitoring service was integrated into operation optimization frameworks. These frameworks demonstrated the potential to increase the energy performance of a large-scale heat pump by up to 3 % and reduce operational costs by up to 5 %.

Lastly, three predictive maintenance frameworks based on digital twins were developed for different case studies. These frameworks enabled the prediction of various faults and the scheduling of maintenance activities using data-driven methods and physics-based components.

Overall, the thesis highlights the potential of digital twin-based services to enhance energy efficiency and reliability in large-scale heat pump systems, paving the way for further digitalization in this sector.

Please email the summary to the PhD secretary at the department