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Thu-Af-Po.05-03: Real-time temperature distribution prediction for superconducting magnet cooling process based on improved physical information neural network

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The background magnets of the superconducting conductor test facility (Super-X) are composed of CICC-wound superconducting coils, weighing approximately 100 tons, and are actively cooled using supercritical helium. During the cooling process, fluctuations in the chiller's power and the complexity of heat transfer may cause deviations from the designed cooling process. These factors hinder the efficient cooling of the superconducting magnets to their operating temperature. In this paper, we propose a deep learning model that integrates physical laws with neural networks to enable real-time monitoring of the temperature distribution across the entire magnet during the cooling process, as well as to make cooling predictions. We simplify the magnet heat transfer model and incorporate it into a multi-scale Convolutional Neural Network (CNN)-Long Short-Term Memory (LSTM) network. The multi-scale CNN performs feature extraction at various scales, capturing both local and global information from the input parameters. The LSTM network incorporates an attention mechanism to effectively process information from longer time series. The boundary conditions and heat balance equations are incorporated into the loss function, thereby enhancing the interpretability, robustness, and generalization of the model. The results show that the model predicts the magnet temperature distribution with an error of less than 1K and requires less than 500 ms, demonstrating its ability to accurately predict the magnet's temperature distribution. This work can guide the operation of the magnet cooling process and provide valuable insights for optimizing future magnet cooling designs.

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