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C1Or2D-02: Investigation and perspectives of using Graph Neural Networks to model complex systems: the simulation of the helium II bayonet heat exchanger in the LHC

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Large cryogenic systems, like those installed at CERN, are complex systems relying on many diverse physical processes and phenomena that are difficult to simulate and monitor in detail. With only a limited number of properties measured and made available for monitoring and control purposes, several processes contributing to the dynamics of the systems are ignored and therefore reduce the accuracy and capability of the model to track, predict and anticipate. Accurate analytical or numerical computer modelling can be developed to simulate the non-linear dynamics of the processes but are complex, computationally intensive, and cumbersome to test, validate and implement with different configurations and limited measurements of the hidden properties.

In this work, we are presenting our investigation of using Graph Neural Networks (GNN) to build a model of the helium II bayonet heat exchanger operating in the LHC at CERN.

GNNs are artificial neural networks for processing data that can be represented in terms of graphs and have recently become quite popular in the High-Energy Physics field because of reduced computational cost and generalisation capabilities.

We are proposing to use a hybrid machine learning approach, where the parameters of the GNN model are estimated by a combination of supervised learning algorithms trained on experimental data and bounding physics equations and parameters.

The GNN model was initially trained on data from the experiments performed on the LHC prototype magnet Strings and validated on data extracted during the operation of the LHC machine.

We demonstrate the model accuracy, repeatability, and robustness in various configurations. The model is also well inspectable and explainable providing the time evolution of all variables.

We report on the results and expected application for predictive control, diagnostic and operators training as well as its extension to other systems to obtain a global cryogenic system model.

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