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Deep learning based plasma response models to 3D external magnetic field perturbations in EAST

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Three-dimensional (3D) fields in tokamak are primarily generated by Resonant Magnetic Perturbation (RMP) coils, which produce magnetic fields with small intentional toroidal asymmetries. When a toroidally symmetric tokamak plasma is subjected to these toroidally asymmetric magnetic perturbations, a new equilibrium emerges. This equilibrium incorporates perturbed currents, magnetic fields, pressures, and displacements, representing the plasma's response to the applied three-dimensional fields. Extensive experiments have demonstrated that three-dimensional magnetic perturbations can induce significant impacts on transport and energy confinement within tokamaks. Concurrently, they lead to substantial modifications in particle and heat flux distributions onto plasma-facing components such as the vacuum vessel wall and divertor targets. Therefore, three-dimensional fields phenomena are closely associated with plasma confinement and stability in tokamak. The plasma response plays a crucial role in understanding the underlying physical mechanisms behind three-dimensional fields phenomena, making the modeling of plasma responses under three-dimensional external magnetic fields particularly significant [1].

In this work, a dataset was constructed based on the EAST experimental database, incorporating supervised learning of q_{95}, β_N, n_e, l_i, B_t, RMP signals, and plasma response. Two response prediction models were trained using deep learning neural networks [2-4]. Both models achieved amplitude prediction scores exceeding 0.85 (on a scale from 0 to 1) and phase prediction scores exceeding 0.9 (on a scale from 0 to 1) when compared to experimental measurements. The response model successfully predicts the response of the shot 127087, as shown in Figure 2. Additionally, the real-time model, leveraging the fast computational capabilities of the neural network, can meet the demands of real-time experimental predictions. The physical analysis model directly establishes a mapping between the input physical signals and the plasma response, enabling the analysis of the response's dependence on plasma state parameters through experimental data.

References

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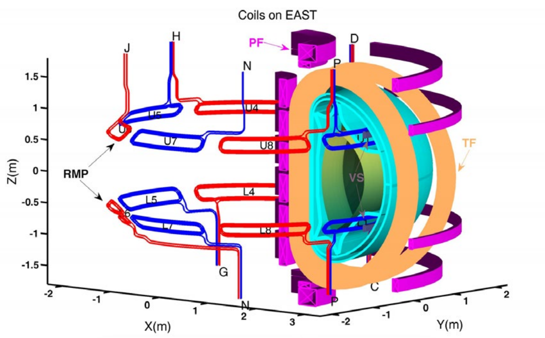

Figure 1. The RMP system on the EAST tokamak

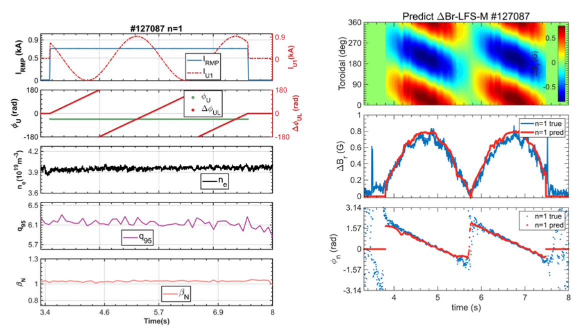

Figure 2. The input signals and prediction results of physical analysis model based deep learning