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Multi-scale spatio-temporal features fusion method for fault diagnosis of NPPs under high noise

摘要

核能对于优化能源结构和促进可持续发展至关重要而核电站的准确故障诊断对安全至关重要因为操作人员依赖经验和知识可能在压力下导致错误当前不依赖经验或先验知识的数据驱动故障诊断方法被认为是最有前景的方法之一该方法对原始数据要求较高而核电站常受到电磁干扰或背景噪声影响这些干扰可能掩盖早期故障的细微特征导致误诊或漏诊可能引发严重事故为解决这个问题我们提出基于多尺度学习和时空特征融合的方法通过使用 CNN 构建多尺度学习框架并将其与 LSTM 结合进行时空特征融合为验证该方法有效性我们在模拟数据中测试了三种典型场景：故障类型诊断、故障严重程度诊断以及多故障并发条件下的故障诊断并将我们的方法与 CNN、LSTM、WDCNN 和 MBSCNN 等模型进行对比结果表明在信噪比-100 的高噪声环境下我们提出的模型故障诊断准确率超过 99% 优于基准模型。

关键词

故障诊断，时空特征融合，多尺度特征提取

Abstract

Nuclear energy is vital for optimizing the energy mix and promoting sustainable development, and accurate fault diagnosis in NPPs is crucial for safety, as operators' reliance on experience and knowledge may lead to errors under pressure. Currently, the data-driven fault diagnosis approach that does not rely on experience or prior knowledge is considered one of the most promising methods. This method has high requirements for raw data, while NPPs often experience interference from electromagnetic disturbances or background noise, which can obscure the subtle features of early faults, leading to misdiagnosis or missed diagnosis, potentially resulting in severe accidents. To address this issue, we propose a method based on multi-scale learning and spatiotemporal feature fusion. We have constructed a multi-scale learning framework using CNNs and integrated it with LSTM for spatiotemporal feature fusion. To validate the effectiveness of the proposed method, we tested it in three typical scenarios on simulated data: fault type diagnosis, fault severity diagnosis, and fault diagnosis under multiple fault concurrent conditions. We compared our method with models such as CNN, LSTM, WDCNN, and MBSCNN. The results demonstrate that our proposed model achieves a fault diagnosis accuracy of over 99\% under high noise conditions with an SNR of -100, outperforming the baseline models.

Keywords

Fault diagnosis , Spatio-temporal features fusion, Multi-scale learning

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