

## ABSTRACT

Power converters are vital in aerospace, electric vehicles, renewable energy, and other safety-critical systems, where their failures can disrupt entire missions. However, their reliability assessment is challenging due to complex component interdependencies, gradual degradation, and simultaneous multi-component faults. This research is an attempt to address these challenges by developing integrated frameworks for reliability modelling, anomaly detection, fault diagnosis, and Remaining Useful Life (RUL) prediction of DC-DC converters. A probabilistic reliability framework is proposed by combining RIAC 217Plus models predicted failure rates with the Bayesian Belief Networks (BBNs). Two-state and multi-state BBN models are developed to identify critical subsystems, incorporate physics-based degradation models, and capture sequential dependent failures, enabling dynamic updates of system reliability as degradation progresses. Accelerated life testing data taken from the literature is further used to propose a Weibull-PHM model that incorporates thermal stress as a covariate, providing a better reliability prediction than classical models. To address multi-component fault progression, a systematic anomaly detection methodology is introduced using statistical features of converter output voltage and a Fault Severity Index (FSI) that quantifies degradation severity and track's fault evolution in SEPIC, Boost, and Flyback converters. Data-driven and Deep Learning (DL) methods are also developed for robust fault diagnosis and RUL prediction. Multi-sensor fusion with 1D-CNN achieves accurate classification of single and multiple faults under varying operating conditions, while Bi-RNN models capture simultaneous degradation of components. Finally, an LSTM-based prognostic model links deviations in performance parameters to RUL, enabling early prediction of failures. Overall, this work combines probabilistic modelling with machine learning to advance system-level reliability assessment, enabling early fault detection, accurate diagnostics, and predictive maintenance of power converters used in mission- and safety-critical applications.

**Keywords:** Prognostics and Health Management (PHM), Reliability Prediction, Power Converter, RUL Prediction, Deep Learning (DL), Fault Classification