

Diagnosis of Wiring Networks Using Reflectometry and the Inception-ResNet V2 Network

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Fault diagnosis in wiring networks is crucial for reliable industrial system operation. This paper introduces a novel method combining Time Domain Reflectometry (TDR) with the Inception-ResNet V2 network for fault diagnosis. By converting TDR signals into images, resized images are fed into the Inception-ResNet V2 network using transfer learning. The benefits of this method include efficient convolutions for real-time detection, and no need for predefined transformations or manual feature extraction. Its feasibility is proven with application to a common wiring network configuration.

Index Terms—Wiring Network, Diagnosis, Reflectometry, Inception-ResNet V2, Transfer Learning.

I. INTRODUCTION

The Wiring networks are crucial in modern infrastructure, transmitting power, signals, and data. Their complexity and age lead to degradation and faults, with potentially severe consequences, as shown by wiring defects in airplane crashes [1]. Effective diagnostic methods are needed to prevent these issues. Time Domain Reflectometry (TDR) is a prominent and effective technique for fault diagnosis, using test signals and echo analysis to detect anomalies [1]. Relying only on TDR responses, is often insufficient to accurately determine wiring configurations or their condition. Extracting detailed information from these signal alone is challenging and sometimes impossible. Thus, integrating TDR with advanced methods is recommended to improve understanding and insight into wire configurations. Combining TDR with such techniques allows for richer information extraction, offering a comprehensive view of wiring characteristics. Two advanced methods combined with TDR for diagnosing wiring networks are iterative and machine learning techniques. Iterative methods use optimization algorithms like Genetic Algorithm [2] and Particle Swarm Optimization [3] to minimize the difference between measured and simulated signals, facing challenges like computational complexity and sensitivity to initial conditions. Machine learning methods, using algorithms like Neural Network [4], Support Vector Machines [5] and Random Forests [6], create models for diagnostics but face issues like manual feature engineering and scalability. Both approaches encounter difficulties in handling various fault scenarios, addressing local and global minima, and overcoming real-time application challenges. The paper presents a novel method for diagnosing wiring networks by transforming TDR responses into images and applying the Inception-ResNet V2 network for image processing. This approach integrates signal and image processing via deep learning, offering advantages over traditional optimization and

machine learning methods, such as reduced computational complexity and real-time diagnosis with precise accuracy. Inception-ResNet V2 facilitates automatic feature extraction, overcoming the limitations of manual feature engineering. The method involves three steps: using a forward model to simulate network behavior under various faults to generate TDR responses, processing these responses into labeled images to create an offline dataset for training the Inception-ResNet V2 model, and using the trained model to diagnose the wiring network based on resized images of measured responses, in order to identify, locate, and characterize faults accurately.

II. FORWARD MODEL FOR GENERATING TDR RESPONSES

The first step of the proposed method aims to create a model for simulating the response of a wiring network. This involves using a RLCG circuit model that govern propagation equation solved numerically using a Finite-Difference Time-Domain (FDTD) method. The model can simulate different wiring network topologies and fault types, enabling a comprehensive examination of various scenarios. The validation of this model has been previously established in [2], ensuring its reliability and accuracy.

III. METHODOLOGY

The methodology consists of two distinct processes: an offline process and an online process.

A. Offline process

The goal of the offline process is to transform the TDR signals into images and set up and verify various pre-trained Inception-ResNet V2 classification and regression models, as depicted in Figure 1. The various stages of the off-line procedure are outlined below.

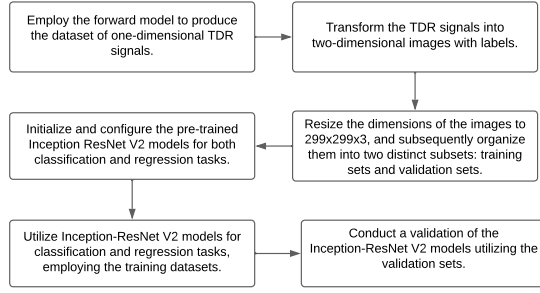


Fig. 1. Workflow of the offline process.

B. Online process

The online process involves three key phases: detection, localization, and characterization. In this study, we propose a novel approach to address these phases, as shown in Figure 2.

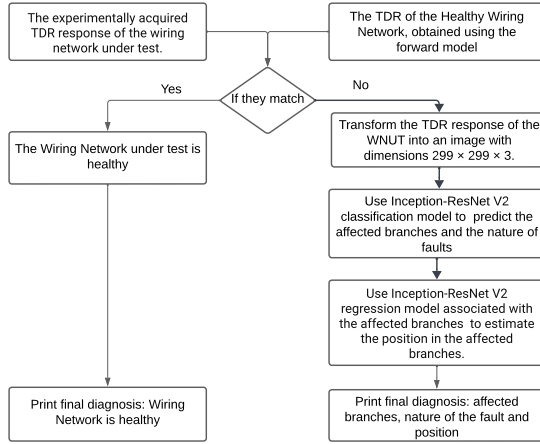


Fig. 2. Workflow of the online process.

IV. NUMERICAL RESULTS

Consider a Y-shaped wiring network where a particular branch is affected by a hard fault. Figure 3(b) provides a comparative analysis between the TDR response of the Wiring Network Under Test, with a fault at L2, obtained experimentally, and the TDR response of the fault-free wiring network derived using the forward model.

A. Offline process

To create a dataset for the Y-shaped network with a single hard fault, the forward model simulates the wiring network's behavior under various fault scenarios, generating TDR responses. The TDR responses are processed into labeled images, each linked to a specific TDR response and class label. Table I compares the accuracy of the proposed method against other methods during validation on a Y-shaped wiring network with a hard fault. The dataset is split 80% for training and 20% for validation, with each classifier trained 10 times using random splits. Results show the proposed method's superior performance.

B. Online process

Initially, an RMSE value above a threshold is obtained, indicating potential faults and confirming an unhealthy network.

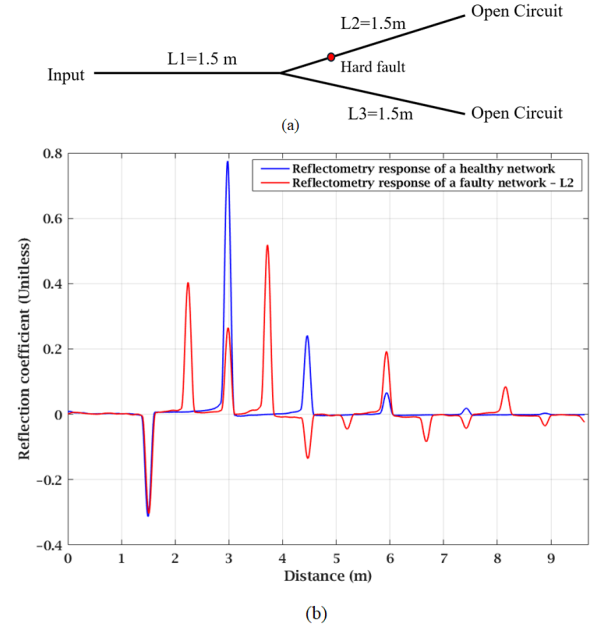


Fig. 3. (a) Y-shaped network affected by one hard fault (b) TDR signals for healthy and faulted networks.

Methods	Proposed Method	Method ([5])	Method ([6])
Accuracy %	98,27	95,45	94.54

TABLE I
COMPARATIVE ANALYSIS OF ACCURACY

Subsequently, the algorithm progresses to the localization and characterization phases. The Inception-ResNet V2 classifier identified the fault in branch L2 as an open-circuit hard fault with 98.7% confidence. The Inception-ResNet V2 regression model then pinpointed the fault location at 0.23 meters along L2. The reconstructed wiring network is visually represented in Figure 4

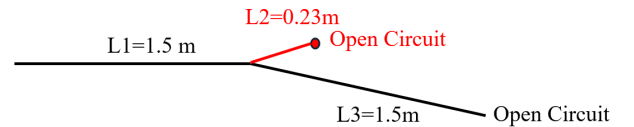


Fig. 4. The reconstructed wiring network

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