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Diagnosis of wiring networks using Particle Swarm Optimization and Genetic Algorithms ☆

M.K. Smail [a,*], H.R.E.H. Bouchekara [b], L. Pichon [c], H. Boudjefdjouf [b,d], R. Mehasni [b]

[a] Université Paris-Est, IFSTTAR, Boulevard Newton, F-77747 Champs sur Marne, France
[b] Electrical Engineering Laboratory of Constantine, LEC, Department of Electrical Engineering, University of Constantine 1, 25000 Constantine, Algeria
[c] Laboratoire de Génie Electrique de Paris, UMR 8507 CNRS, SUPELEC, Université Paris-Sud, Université Pierre et Marie Curie, 91192 Gif-sur Yvette cedex, France
[d] UAq EMC Laboratory, Dept of Industrial and Information Engineering and Economics, via G. Gronchi, 18, 67100 L'Aquila, Italy

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ABSTRACT

The performances of Particle Swarm Optimization and Genetic Algorithm have been compared to develop a methodology for wiring network diagnosis allowing the detection, localization and characterization of faults. Two complementary steps are addressed. In the first step the direct problem is modeled using RLCG circuit parameters. Then the Finite Difference Time Domain method is used to solve the telegrapher's equations. This model provides a simple and accurate method to simulate Time Domain Reflectometry responses. In the second step the optimization methods are combined with the wire propagation model to solve the inverse problem and to deduce physical information's about defects from the reflectometry response. Several configurations are studied in order to demonstrate the applicability of each approach. Further, in order to validate the obtained results for both inversion techniques, they are compared with experimental measurements.

1. Introduction

Fault occurrence in wiring is a major cause for concern in aircrafts, cars and other transport means. As transport mean wires age they become brittle and are subject to several electrical, chemical and mechanical stresses. This leads to the occurrence of defects in the wiring. Arcs in aircraft wires are involved in several serious accidents including the explosion of Swiss Air Flight 111 and TWA Flight 800 [1]. In this area, reliability becomes a safety issue.

There are several emerging technologies that may help to locate and characterize faults in wiring networks. The most widely used technique for fault location in automobile wiring is reflectometry [1]. It is based on the same principle of radar. A high frequency electrical signal is sent down the wire, where it reflects from any impedance discontinuity such as open or short circuits. The difference (time delay or phase shift) between the incident and reflected signal is used to locate the fault on the wire. The nature of the input signal is used to classify each type of reflectometry: Time Domain Reflectometry (TDR) uses a fast rise time pulse [2], Frequency Domain Reflectometry (FDR) uses a sine wave signal [3], Sequence Time Domain Reflectometry (STDR) uses a pseudo-noise (PN) code, and Spread Sequence Time Domain Reflectometry (SSTDR) used a sine-wave-modulated PN code [4]. These last two techniques can test wire on live. Also a new method called, Time–Frequency Domain Reflectometry (TFDR) was presented in [5]. All these methods present some limitations to characterize the impedance of the fault as well as the position in some cases.

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* Corresponding author.
E-mail address: mostafa.kamel.smail@gmail.com (M.K. Smail).

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Interpreting the results obtained with reflectometry instrument for a wiring network requires great expertise, as the reflectometry response can be very complex. Moreover, the reflectometry response itself is not self-sufficient to identify and locate the defects in wiring networks. There is the need to solve efficiently the inverse problem which consists of deducing some knowledge about the defects from the response at the input of the line.

Several methods have been proposed to locate and characterize faults on wiring networks. In a baseline approach, the response of the faulty network is compared with either the pre-measured or simulated response of its (known) healthy configuration. With this method it is extremely difficult to detect and locate defects in faulty wiring networks affected by two or more faults. Only the first fault near to the test point can be detected. Also the location of the fault on the branches cannot be identified. In Bayesian approaches, the essential idea is to assign a quantifiable measure of certainty of belief to all possible variables (permittivity, impedance, location of the faults) [6]. In [7] Time domain signal restoration and parameter reconstruction of a simple nonuniform RLCG transmission line is performed using the wave-splitting technique and the compact Green functions technique. These two last methods allow to find faults in simple electrical wirings only.

Wiring networks can be affected by two types of faults namely soft and hard faults. Soft ones are created by the change of the impedance along the line due to simple deformation in the wire or local modification of the electrical parameters [8]. Hard ones are open and short circuits. For the first type of faults, the reflectometry response of the faulty network presents a simple deviation or variation versus the impedance of the fault in the defects location. In the case of hard faults, both the structure of network and the response change.

In this paper, a comparative evaluation of Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) for detection, localization and characterization of defects in faulty wiring networks using measured reflectometry response is achieved. Solving the inverse problem, when a hard fault occurs consists of reconstructing the structure of the faulty wiring network by minimizing the error between the reflectometry response and the one given by the direct model. This model describes the propagation of the electromagnetic wave along Multiconductors Transmission Lines (MTL) in the time domain.

The reminder of this paper is organized as follow: in Section 2 the direct model and network analysis are presented. In Section 3 the resolution of the inverse problem using GA and PSO are described. In Section 4 the inversion results obtained using GA and PSO are compared to the measured ones. Finally, the conclusion is drawn in Section 5.

2. The direct model

The propagation in a MTL (including n conductors) can be modeled by a RLCG circuit model [9]. The position along the line is denoted by z and time is denoted by t. The $n \times n$ matrices $[R]$ (resistance), $[L]$ (inductance), $[C]$ (capacitance) and $[G]$ (conductance) contain the per-unit-length parameters which are computed either by finite element approach or analytically for simple configurations.

The model is based on the telegrapher's equations. The wave propagation equations are solved using the Finite Difference Time Domain (FDTD) method.

In order to validate the direct model, we have chosen a MTL composed of three conductors with a characteristic impedance of 120 ohms and a length of 1 m as shown in Fig. 1. The height above the ground plane is 5 cm. To study the twisted wire configuration (Fig. 1(a)) by the transmission line theory, it has been discretized into small section (S_i) of same length Δ

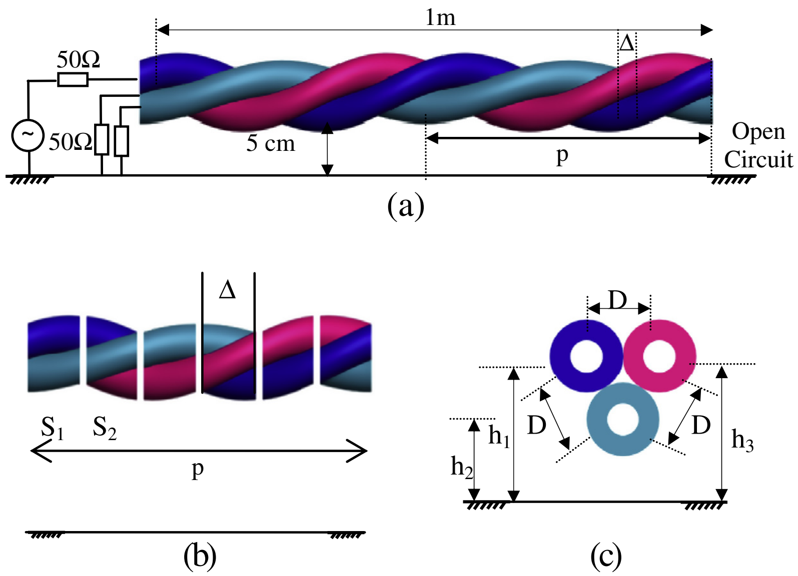

Fig. 1. (a) Twisted wire configuration, (b) discretization into uniform MTL sections S_i of length $\Delta = p/N$ and (c) cross sectional of MTL.