On the Validation of Models of Large Complex Electrical Systems

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ABSTRACT

The broad topic of verification and validation (V&V) of simulation model is considered, narrowing the scope to electric network models, using briefly electric traction systems as the working example. Definitions, properties and requirements of the validation process, of the model characteristics and of simulation test methods are considered: the focus is on the background and the methods to address the general problem of model validation with emphasis on the use of experimental measured data and how to characterize them to assess the required metrological quality. Depending on the method approached for model validation, the metrological quality may take the form of uncertainty, consistency and credibility. Bibliography is selected as the most representative for the respective topics of the vast V&V subject and is believed to represent a comprehensive, yet synthetic, reference. This work is intended as a general basis for a more detailed and specific analysis of V&V techniques applied to electric simulation and models.

Keywords: Electric Models, Electric Network Models, Electric Simulation, Validation Process, Verification and Validation (V&V)

1. INTRODUCTION

Numerical models are widely used in all fields of physics and engineering, when experiments on the real system under study (s.u.s.) are expensive or even impossible, when the influence of some parameters is of interest and is not under operator’s control, when extreme conditions or worst cases are to be tested, but are not physically feasible, perfectly repeatable, or are even beyond s.u.s. capability. A working example of a
large complex electrical system is a railway traction system (Ogunsola & Mariscotti, 2012; Mariscotti, 2003), that features also strict requirements for safety and its demonstration through simulation.

A railway is a very large network with an “unpractical” system for power distribution, with trains lying on the running rails below overhead conductors, from which they collect power through the pantographs. The return current flows back to the Electric Substations (ESS) through the so called return circuit. The power distribution scheme is single phase at industrial frequency or dc.

The specific arrangement and the peculiarities of an electrified railway require that the electrical parameters are calculated for conductors of very different shapes and materials, with different distance from the boundaries of the electromagnetic problem and subject to several factors, that lead to a significant uncertainty on their value (temperature, dirt, ageing of surfaces, moisture, type of sleepers, ballast and track, etc.) (Mariscotti, 2011; Mariscotti & Pozzobon, 2004a; Mariscotti & Pozzobon, 2004b; Mariscotti & Pozzobon, 2004c; Mariscotti & Pozzobon, 2005; Paul, 1994; Mariscotti, Ruscelli & Vanti, 2010).

The verification of a model is the evaluation of the correspondence to the requirements, even for single modules during their development. The validation of a simulation model aims at verifying that it meets its intended use, in terms of overall requirements and user’s expectations. The verification phase reviews intermediate elements, by means of static analysis techniques (inspections and reviews) and possibly dynamic techniques (execution of test runs of the simulator modules, maybe assisted by synthetic data). The validation is performed on the complete product (the simulator) and uses dynamic techniques, by executing test runs on reference cases (Naik & Tripathy, 2008). A very comprehensive analysis and an interesting theoretical framework for complex systems of different nature is presented in Min, Yan and Wang (2010). Testing of a software tool for scientific purposes is accompanied by the evaluation of the accuracy of its results with respect to reference experimental data, both characterized by their uncertainty (Min, Yan & Wang, 2010). Since a model is an abstraction of a system, perfect representation is not expected nor really required (Balci, 1997). Shannon (1975) indicates that “it is not at all certain that it is even theoretically possible to establish if we have an absolutely valid model”, so that the outcome of VV&T (Verification, Validation and Testing) applied to a model should be a degree of credibility.

Numeric models are being used more and more often for the evaluation of worst and critical cases, in order to assess system safety. For railway systems (and by extension any other electric transportation system) the relationship between safety and EMC brings to very complex, expensive and time consuming assessment procedures. The latter benefit from, or are even unpractical without, adequate models of the system. This is readily explained if the possibility is considered of analyzing extreme system configurations and parameter values, and evaluating the statistical distributions of network response. The use of numerical models is also suggested by the EU Directives on interoperability (EU TSI, 2002) and related standards for the evaluation
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