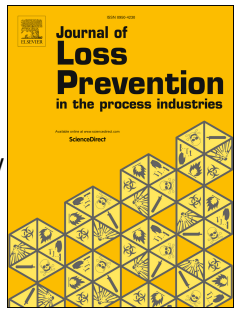
Accepted Manuscript



Uncertainty handling in safety instrumented systems according to IEC 61508 and new proposal based on coupling Monte Carlo analysis and fuzzy sets

Fares Innal, Mourad Chebila, Yves Dutuit

PII: S0950-4230(16)30203-0

DOI: 10.1016/j.jlp.2016.07.028

Reference: JLPP 3284

To appear in: *Journal of Loss Prevention in the Process Industries*

Received Date: 21 September 2015

Revised Date: 20 April 2016

Accepted Date: 27 July 2016

Please cite this article as: Innal, F., Chebila, M., Dutuit, Y., Uncertainty handling in safety instrumented systems according to IEC 61508 and new proposal based on coupling Monte Carlo analysis and fuzzy sets, *Journal of Loss Prevention in the Process Industries* (2016), doi: 10.1016/j.jlp.2016.07.028.

Uncertainty handling in safety instrumented systems according to IEC 61508 and new proposal based on coupling Monte Carlo analysis and fuzzy sets

Fares Innal [a,*], Mourad Chebila [b], Yves Dutuit [c]

[a]Department of Production and Quality Engineering, Norwegian University of Science and Technology, NO 7491, Trondheim, Norway

[b]Batna University, IHSI-LRPI, avenue Chahid Mohamed Boukhlouf, 05000 Batna, Algeria

[c]TOTAL Professeurs Associés, 38, rue du Prieuré, 33170 Gradignan, France

Abstract

Safety instrumented systems must be designed, built and operated to meet tolerable risk level as required regulatory agencies. This requirement is closely related to their probabilistic performance measures which are either theiraverage probability of dangerous failure on demand (PFD_{avg}) or their average frequency of failure (PFH: Probability of Failure per Hour). The objectof this work isthe SIS performances evaluationtaking intoaccountthe uncertaintiesrelated tothe different parameters thatcomeinto play: failure rate (λ), common cause failure proportion (β), diagnostic coverage (DC), etc. This leads to an accurate and therefore safe assessment of the safety integrity level (SIL) inherent to safety functions performed by such systems. This aim is in keeping with the requirement of the IEC 61508 standard with respect to handling uncertainty. In this paper we first explain in detail the IEC 61508 approach for handling uncertainty. Afterwards, we propose an approach that combines (i) Monte Carlo analysis (MCA) and (ii) fuzzy sets. Indeed, the first method is appropriate when representative statistical data are available (using pdf of the relating parameters), while the latter applies in the case characterized by vague and subjective information (using membership function). The proposed approach is fully supported with a suitable computer code developed under the MATLAB environment.

Keywords: Safety instrumented system (SIS), Safety integrity level, Uncertainty propagation, Monte Carlo simulation, Fuzzy sets.

1. Introduction

Nowadays, most of industrial processes, especially the characteristic parameters of their behavior, are constantly monitored by devices qualified as safety instrumented systems (SIS). A SIS is conventionally made up of three main subsystems: sensing elements (S), logic solvers (LS) and final elements (FE). The primary objective assigned to such systems is to detect the occurrence of a hazardous situation, when predetermined conditions are violated such as set points for pressure, temperature, level, etc., that could lead to an accident and then implement a set of necessary reactions to take the system under control to a safe state. In this context, the IEC 61508 (IEC 61508, 2010) has been developed as a performance-based standard to define the requirements for SIS regarding the necessary risk reduction. To characterize these requirements, the IEC 61508 uses the concept of safety integrity level (SIL), which is therefore a measure of

* Corresponding author. Tel.: +47 73597102.
*E-mail address:*innal.fares@ntnu.no (F. Innal).