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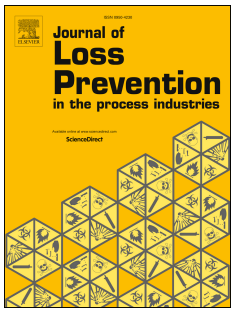

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Reliability assessment for final elements of SISs with time dependent failures

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Abstract:

Reliability assessment for safety-instrumented systems (SISs) plays a vital role in improving the design of SISs. Traditional methods for SIS reliability assessment that assume constant failure rates are, however, not realistic for many final elements of SISs, e.g. electro-mechanical and hydraulic/mechanical actuators that are subject to degradation. This paper presents an approach for the reliability assessment of SIS final elements with time dependent failure rates. Different operational issues, such as partial and full testing, are investigated for their effects on reliability of SISs. Approximation formulas for evaluation of average probability of failure on demand (PFD_{avg}) involving degradation are developed within different subsequent proof testing intervals, and Weibull distributions are adopted to model the degradation processes of the final elements. The corresponding numerical results of PFD_{avg} from the set of the derived formulations are validated by Petri nets models that are developed for different scenarios. Shutdown valves installed as part of a high integrity pressure protection system are analyzed as the case, to illustrate the feasibility of the proposed approach, and also demonstrate that the approximation can provide possibilities for testing strategies design and optimization.

Key words: Final elements, Reliability assessment, Partial tests, Approximation formulas, Petri nets models

1. Introduction

Safety-instrumented systems (SISs) are installed in many industries to detect the onset of hazardous events, and automatically or manually manage such situations to avoid occurrence of accidents. A SIS generally consists of sensors (e.g. pressure transmitters), logic solver(s) (e.g. programmable logic controllers) and final elements (e.g. valves, breakers and switches). Final elements may be regarded as the most vital subsystems as they (upon events like process upsets) interact directly with the process, but due to the force and motion to be exerted when action is asked, these devices are rather vulnerable to creeping degradation processes. Therefore their preparedness to act when required has to be checked rather frequently. The final elements are normally passive during normal operation, and they may for this reason be subjected to failures that cannot be revealed unless a test is carried out (or a real demand for safety function occurs). Such failures are therefore regarded as hidden (or undetected) dangerous failure. Periodical tests are able to reveal these hidden failures, and the average probability of failures on demand (PFD_{avg}) is the suggested reliability measure for safety instrumented functions (SIFs) carried out by a SIS when low-demand mode is assumed [1]. In current literature regarding reliability assessment, the effects of periodical proof tests, where all hidden failures are assumed to be discovered (so called full proof tests), have been well studied [2-4].

However, for subsea exploration and production, frequent proof tests may be not realistic. Taking shutdown valves of SISs final elements for instance, full proof testing (FT) on these valves include regular full stroke operation and leakage testing. FT can fully verify that the valves close and keep tight on demand, but FT may also bring some negative impacts to valves (e.g. wear of the valve seat area) due to strong stresses [5]. In addition, the shutdown of the whole system needed in proof tests can lead to some other operational problems, e.g. during start-up [5, 6]. Therefore, partial testing (PT) has been introduced in recent years as a supplement to FT [5, 7, 8].