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The effect of parameter uncertainty on achieved safety integrity of safety system

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Abstract

This paper introduces the concept of safety-related (SR) uncertainty and the methodology to measure SR uncertainty. SR uncertainty is concerned with the effect of parameter uncertainty on the uncertainty of system *unsafety* (defined with respect to achieve safety integrity level), which is in direct contrast to the effect on overall system uncertainty. The properties of SR uncertainty are discussed and its significance in analyzing safety systems is highlighted. The conventional global sensitivity analysis (GSA) to handle overall uncertainty is inappropriate when SR uncertainty is of interest. We present and discuss four methods to measure SR uncertainty. Three examples are used to demonstrate the effectiveness of the proposed methods in comparison with GSA.

Keywords

Safety system; Importance measure; Safety-related uncertainty; Global sensitivity analysis; Safety integrity level

Figures and tables from this article:

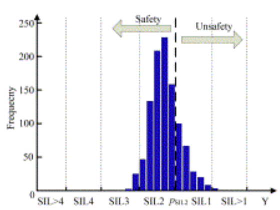

Fig. 1. Distribution of probability of failure on demand.

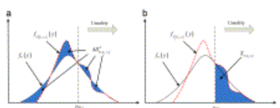

Fig. 2. Density $f_Y(y)$ (solid) and conditional density $f_{Y|X_i=x_i^*}(y)$ (dashed).

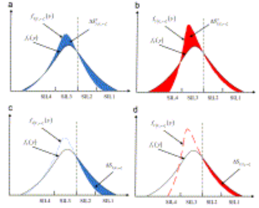

Fig. 3. Density $f_Y(y)$ and conditional density $f_{Y|X_i=x_i^*}(y)$, i=1,2. (a) and (b) overall uncertainty; (c) and (d): SR uncertainty.

Figure options

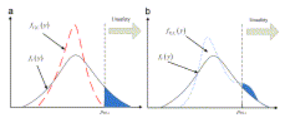

Fig. 4. Reduction in the probability of unsafety with eliminated uncertainty in X_i.

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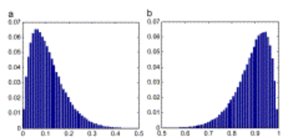

Fig. 5. Distribution of parameters: (a) X_1 and (b) X_2.

Figure options

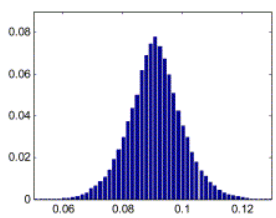

Fig. 6. Distribution of model output Y.

Figure options

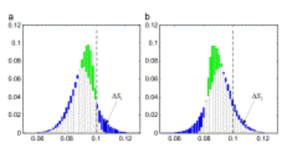

Fig. 7. Distribution of model output Y with reduced uncertainty of (a) X_1 and (b) X_2.

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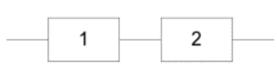

Fig. 8. System with two components in series.

Figure options

Table 1. Safety integrity levels according to the IEC 61508 standard.

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Table 2. Statistical properties of the parameters and the model output.

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Table 3. SR uncertainty measures (M2, and M3) calculated by varying α.

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Table 4. Uncertainty importance measures and their ranking (bracketed, "E" refers to equal ranking).

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Table 5. Uncertainty importance measures and their ranking (bracketed, "E" refers to equal ranking).

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Table 6. Parameters used in the 2oo3 model.

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Table 7. Uncertainty importance measures and their ranking.

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Table 8. Uncertainty importance measures and their ranking (β and DC_D are changed to conform to beta distributions).

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