SIL and Functional Safety

Quick reference for instrumentation and control engineers

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instrumentationblog.in

SIL bands (low demand, IEC 61511)

SIL	PFDavg	RRF
1	10^{-2} to 10^{-1}	10 to 100
2	10^{-3} to 10^{-2}	100 to 1000
3	10^{-4} to 10^{-3}	1000 to 10,000
4	10^{-5} to 10^{-4}	10,000 to 100,000

High demand (PFH per hour)

SIL	PFH
1	10^{-6} to 10^{-5}
2	10^{-7} to 10^{-6}
3	10^{-8} to 10^{-7}
4	10^{-9} to 10^{-8}

High demand: more than one demand per year.

PFDavg (simplified, IEC 61508-6)

1oo1	$\lambda_{DU} \times TI \div 2$
1oo2	$(\lambda_{DU}\ TI)^2 \div 3 + \beta\ \lambda_{DU}\ TI \div 2$
2oo3	$(\lambda_{DU}\ TI)^2 + \beta\ \lambda_{DU}\ TI \div 2$
2oo2	$\lambda_{DU} \times TI$
RRF	$1 \div PFDavg$
Imperfect test	$PTC\ \lambda_{DU}\ TI \div 2 + (1 - PTC)\ \lambda_{DU}\ MT \div 2$

Failure fractions

Total rate	$\lambda = \lambda_{SD} + \lambda_{SU} + \lambda_{DD} + \lambda_{DU}$
SFF	$(\lambda_S + \lambda_{DD}) \div \lambda$
Diagnostic coverage	$\lambda_{DD} \div (\lambda_{DD} + \lambda_{DU})$
MTBF	$1 \div \lambda$
1 FIT	1 failure per 10^9 h
Spurious trips 1oo1	$STR \approx \lambda_S$

Minimum HFT (IEC 61511 Ed. 2)

SIL	HFT
1	0
2 (low demand)	0
2 (high demand)	1
3	1
4	2

Voting at a glance

Voting	HFT	Spurious trips
1oo1	0	Base
1oo2	1	About double
2oo2	0	Lowest
2oo3	1	Low

LOPA

Mitigated frequency	$f = f_{IE} \times \Pi\ PFD_{IPL} \times$ modifiers
Required RRF	$f \div f_{tolerable}$
Example	$0.2 \times 0.1 \times 0.1 = 2 \times 10^{-3}$ /yr; target 10^{-5} → RRF 200 → SIL 2

Typical IPL credits

Layer	PFD
BPCS loop (maximum claim)	0.1
Operator response to alarm (enough time)	often 0.1
Relief valve	often 0.01
SIF	per SIL

Use your company LOPA rules; credits must be independent, effective and auditable.

Proof test essentials

- Test interval in the calculation must match real practice.
- Record as found condition before repairs.
- Test final elements fully: stroke, time and tight shut off.
- Bypasses: approved, registered, time limited, with compensating measures.