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Definition of Unavailability

$$Q = \text{Unavailability} = \frac{\text{Downtime}}{\text{Total Time}}$$

For a mean cycle of a repairable system...

Downtime = MTTR = Mean Time to Restore (including detection & repair)

Total Time = MTBF = Mean Time Between Failures

MTBF = MTTR + MTTF (Mean Time to Failure)

Therefore:

$$Q = \frac{\text{Downtime}}{\text{Total Time}} = \frac{MTTR}{MTTF + MTTR}$$

If one assumes that MTTR is negligibly small in comparison to MTTF...:

$$MTTR \ll MTTF \Rightarrow MTTF + MTTR \approx MTTF$$

so it follows...

$$Q \approx \frac{MTTR}{MTTF}$$

For a constant failure rate system

λ = failure rate = 1 / MTTF

so it follows...

$$Q \approx \lambda * MTTR$$

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Derivation of 2oo3 DD Contribution

For this case we are concerned with detected dangerous failures which are the repairable failures that make a SIF unavailable.

$$\lambda = \lambda_{DD}$$

so

$$Q_{DD} \approx \lambda_{DD} \, MTTR$$

also, MTTR can be decomposed into the time period required to perform the repair, MRT - Mean Repair Time and the time required to detect the failure, half of the diagnostic test interval $TI_A/2$

$$MTTR = MRT + TI_A/2$$

$$\therefore Q_{DD} = \lambda_{DD} (MRT + TI_A/2) \qquad (1)$$

This is then the unavailability due to diagnosed detected failures for a single component, i.e. 1oo1.

For 2oo3, where components are A, B, and C

$$Q_{2oo3} = (Q_{A\,and\,B}) \; OR \; (Q_{A\,and\,C}) \; OR \; (Q_{B\,and\,C})$$

$$Q_{A\,and\,B} = \lambda_{DD} (MRT + TI_A/2) * \lambda_{DD} (MRT + TI_A/2)$$

$$= \lambda_{DD}^2 (MRT + TI_A/2)^2 \quad [\text{Probability Multiplication}]$$

$$Q_{2oo3,DD} = \lambda_{DD}^2 (MRT + TI_A/2)^2 + \lambda_{DD}^2 (MRT + TI_A/2)^2 + \lambda_{DD}^2 (MRT + TI_A/2)^2$$

$$= 3 \lambda_{DD}^2 (MRT + TI_A/2)^2$$