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Module S

Mitigating System Performance Index (MSPI)

Mitigating System Performance Index

- Purpose: Provide overview of MSPI, with special emphasis on its PRA basis
- Objectives: At the conclusion of this section, students will understand :
 - What is MSPI
 - Why MSPI was developed
 - How MSPI is related to $\triangle CDF$
 - How MSPI includes both unavailability and unreliability
 - How MSPI uses importance measures
- References
 - NEI 99-02, Rev. 4, August 2006
 - NUREG-1816, February 2005

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What is MSPI?

- MSPI is the numerical sum of the deviation between a system's actual unavailability and unreliability values for a calendar quarter and the established baseline values.
- MSPI takes into account plant specific risk importance measures in the calculation.
- MSPI = Unavailability Index + Unreliability Index



MSPI – Systems Monitored/Aspects

- MSPI monitor four front-line systems and support system (e.g., emergency AC power, high pressure injection, secondary cooling, long-term heat removal, service water, etc.).
- Definitions/Aspects monitored:
 - Unavailability the ratio of the hours that a train was out of service for planned or unplanned maintenance or testing during the previous 12 quarters while critical, to the number of critical hours during the previous 12 quarters.
 - Unreliability the probability that a component (failure modes) would not perform its monitored function (defined by PRA success criteria and mission time) when required during the previous 12 quarters.



Why Was MSPI Developed?

- Problems identified with safety system unavailability (SSU) performance indicator
 - Uses short-term unavailability to approximate unreliability
 - Uses same performance threshold regardless of risk significance
 - Potential for double-counting support system failures
 - SSU inconsistent with Maintenance Rule definition of unavailability
 - Inconsistent with indicators promulgated by World Association of Nuclear Operators (WANO) and Institute of Nuclear Power Operations (INPO)
 - Requires plant personnel to track plant data three different ways



Development Timeline

- NRC initiates Risk-Based Performance Indicator program
 - NUREG-1753 issued in 2002
 - Proposed indicators that incorporated risk significance, as measured by SPAR models
 - Plant-specific thresholds for indicators
- MSPI Pilot Program initiated in Summer 2002
 - 20 plants participated
 - Provided V&V of
 - Baseline data
 - Current performance data
 - Importance measures
 - Spreadsheet calculations
 - Overall MSPI results
- NRC gave NEI agreement to proceed with MSPI in August 2004



MSPI Objectives

- Provide a risk-informed, plant specific, indication of mitigating system performance.
 - Reflect risk impact of system availability and reliability at each plant
 - System performance requirements based on PRA system success criteria rather than design basis criteria
 - Monitor most risk significant components



How To Calculate MSPI

- Includes unavailability and unreliability in single risk measure
- MSPI = UAI + URI
 - UAI is Unavailability Index
 - URI is Unreliability Index
- MSPI = \triangle CDF = CDF₁ CDF_o
 - CDF₁ is actual plant performance
 - CDF_o is industry baseline performance
- Because MSPI = \triangle CDF can apply "colors" from SDP
 - − MSPI ≤ 10⁻⁶ GREEN
 - $10^{-6} < MSPI \le 10^{-5}$ WHITE
 - $10^{-5} < MSPI \le 10^{-4} YELLOW$
 - MSPI > 10⁻⁴ RED



Calculating UAI

• UAI is sum of contributions from each train of a monitored system:

$$UAI = \sum_{j=1}^{n} UAI_{tj}$$

• UAI_{ti} is unavailability index for each train



Calculating UAI_t

• $UAI_t = I_B(UA_{PRA}) \quad \Delta UA$ = $I_B(UA_{PRA}) \quad (UA_t - UA_{BLt})$

where:

UA = train unavailability

UA_t = observed train unavailability

UA_{BLt} = baseline train unavailability

 $I_B(UA_{PRA})$ = Birnbaum importance of PRA basic event representing unavailability of train



Calculating UAI_t

Relationship to Fussell-Vesely importance

 $I_{F-V}(X) = \frac{p_X I_B(X)}{CDF}$



Calculating UAI_t

• Substitute into equation for UAI_t

$$UAI_{t} = CDF\left[\frac{I_{F-V}(UA_{PRA})}{UA_{PRA}}\right](UA_{t} - UA_{BLt})$$

where:

CDF = Plant core damage frequency

 $I_{F-V}(UA_{PRA})$ = Fussel Vesely value from plant specific PRA

UA_{PRA} = Plant specific unavailability (probability of being unavailable due to being out for planned or unplanned maintenance)

UA_t = actual unavailable of train t = [Unavailable hours (planned and unplanned) during previous 12 quarters] Critical hours during the previous 12 quarters

UA_{BLt} = historical baseline unavailability value for the train (industry average)



Birnbaum Importance and \Delta CDF

More on Birnbaum importance

$$I_B(x) = \frac{\partial (CDF)}{\partial p_x} = CDF(x=1) - CDF(x=0)$$

- $\triangle CDF \approx \Sigma I_B(x) \triangle p_x$
- Thus UAI is approximately the increase in CDF caused by increase in unavailability of monitored systems



Calculating URI

$$URI = \sum_{j=1}^{n} I_{B,\max} (UR_{PRA,j}) (UR_{BC,j} - UR_{BL,j})$$

I_{B,max} = maximum Birnbaum importance of all basic events for given component

UR_{PRA} = unreliability from PRA

UR_{BC} = Bayesian-corrected unreliability (plantspecific)

UR_{BL} = Industry baseline unreliability



Calculating URI

 Using relationship between Fussell-Vesely and Birnbaum importance gives

$$URI = CDF \sum_{j=1}^{n} \left\{ \left[\frac{I_{F-V}(UR_{PRA,j})}{UR_{PRA,j}} \right]_{max} (UR_{BC,j} - UR_{BL,j}) \right\}$$

- URI includes both demand failures and running failures
 - Details can be found in App. F to NEI 99-02



Calculating URI

Where:

CDF = Plant core damage frequency

I_{F-V}(UR_{PRA}) = Fussel-Vesely value from plant specific PRA (component's failure modes [i.e., MDP fails to run])

UR_{PRA} = Plant specific unreliability (probability of component's failure modes [i.e., MDP fails to run])

 UR_{BC} = Bayesian corrected plant-specific value for the component's specific failure modes [i.e., MDP fails to run] $UR_{BC,d} = (N_d + a)/(a + b + D)$

N_d is the total number of failures of on demand during previous 12 quarters

D is total number of demands during the previous 12 quarters

a and b are parameters of the industry prior, derived from industry experience (Appendix F NEI99-02) $UR_{BC,r} = [(N_r + a)/(T_r + b)] * T_m$

N_r is the total number of failures to run during previous 12 quarters

T_r is total number of run hours during the previous 12 quarters

 T_m is mission time for the component based on PRA model assumption.

a and b are parameters of the industry prior, derived from industry experience (Appendix F NEI99-02)

UR_{BLt} = historical baseline values of unreliability for the component's failure modes [i.e., MDP fails to run]



Color Scale for MSPI

- MSPI = UAI + URI
- MSPI is calculated for each monitored system and compared to risk thresholds
 - MSPI $\leq 10^{-6}$ GREEN
 - $-10^{-6} < MSPI \le 10^{-5}$ WHITE
 - $10^{-5} < MSPI \le 10^{-4} YELLOW$
 - MSPI > 10⁻⁴ RED



MSPI Front-Stop

- Don't want single failure to result in MSPI being WHITE
- For example, expected to see three failures over a three year period. Due to variability, it can be expected to see 2 or 4 failures in three year period.
- It is not appropriate a system should be placed in WHITE band due to expected variation.
- Avoid this by capping most risk-significant failure at 5 10⁻⁷ (from risk-informed Tech. Specs.) (This ensures one failure beyond expected alone doesn't result in MSPI > 1.0 10⁻⁶



MSPI Back-Stop

- For systems with low Birnbaum importance, performance could degrade significantly without MSPI crossing WHITE threshold
- To prevent this, a maximum number of failures is determined as the threshold to the WHITE band, even though the calculated MSPI < 1.0 10⁻⁶
- Appendix E to NUREG-1816 or Appendix F of NEI99-02 gives formula for finding maximum allowed failures, even if MSPI is still GREEN

MSPI Overall Process



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Guidance Documents

- NEI 99-02 Section 2.2
 - Basic Definitions
- NEI 99-02 Appendix F
 - Details of Calculation Methods
 - Detailed Definition of Inputs
- NUREG-1816
 - Technical bases
 - Description of pilot program
 - Recommended enhancements
 - MSPI limitations

