RELAY CHATTER IN SEISMIC PRA

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What is Relay Chatter and why does it matter?

- Relay chatter is a specific components failure mode that is modeled in seismic PRAs
  - Ground motion results in vibration of mechanical and electromechanical devices such as relays (and other similar devices) that may result in spurious contacts
  - Spurious contact (i.e., chattering) results in possible spurious actuation or change of state of components in the plants
  - When a locking/seal-in mechanism/circuit is present, frontline component remains unavailable even after the shaking is finished.

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Paper Content/Focus

- Discuss lessons learned in modeling of relay chatter in numerous Seismic PRAs performed/reviewed to date
- Discuss modeling uncertainties mainly associated with fragility correlation/grouping of relays
- Discuss completeness uncertainties associated with the practical limitation associated with modeling of relays in S-PRAs
- S-PRA analyst perspective

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Framing the Problem
Same Practical Simplification and Assumptions

- PRA Standard addresses explicitly relays with two Supporting Requirements
  - **SPR-B4**: *INCLUDE the effects of the chatter of relays and similar devices in the systems model.*
  - **SFR-F3:** *CALCULATE seismic fragilities for relays identified to be essential and that are included in the systems-analysis model.*
- Rather generic requirements potentially much more far reaching than what is practically feasible in S-PRA.

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Seismic-Induced Initiator Associated with Relay Chatter

- One major simplifying assumption.
- Historically, relay chatter is modeled exclusively in the mitigation portion of the S-PRA logic.
- Older seismic PRAs have a relatively low number of actual initiator and seismic induced LOSP is the last catch-all seismic initiator.
- Loss of support system initiators or ISLOCA may be generated by relay chatter, and so likely every kind of transient
  - North Anna being a case in point

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SC-I vs. Non SC-I

- Second major simplifying assumption.
- Almost all S-PRAs have an assumption that assumes fragilities for all non safety related or non SC-I components have ZERO or very low fragility ➔ The (generic) fragility for offsite power is a good "excuse" to support this assumption
- S-PRA becomes very much black and white
  - We quantify and model fairly well the high magnitude events (that cannot teach us too much beyond what the baseline number would be)
  - The lower g levels (where the insights may be able to suggest effective and smart plant modifications) becomes less insightful.
- Assumption/scope limitation keeps the problem manageable but also make inclusion of non SC-I components in S-PRA a very challenging proposition.
- Even with the two major assumptions discussed above, relay chatter remain an important contributor to almost all most recent S-PRAs.

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Relay Identification – SEL interface

- In the ideal situation, relay identification goes hand in hand with SEL development
  - All components in IE-PRA are credited (2000ish)
  - Additional components are added to address effect of instrumentation (fire PRA can be used to support this task)
  - All non-safety related components are "screened" as they are not credited or credited with very conservative fragilities
  - Relay identification feeds back on the SEL by potentially identifying more cabinets and enclosures that needs to be addressed for fragility evaluation

Relay Identification – SEL interface

- Building on previous evaluations is sometimes a necessity
- IPEEE component list is sometimes used as a “parallel” starting point
  - SMA plants may have only a limited number of components from what is actually included in S-PRA and even aa less complete list of associated relays (i.e., only bad actors relays)
  - SMA plants may have other components that are not needed/credited in S-PRA
    - Pressurizer spray not included in S-PRAs but carried through in SMA list
      - Associated initiating event is normally screened by S-PRAs (transients subsumed in S-LOOP events)
      - Initial relay assessment performed resulted in fragility associated with pressurizer spray being lower than LOOP. This becomes a valid S-PRA initiator.
  - IPEEE/S-PRA lists are in theory a valuable starting point (if maintained in some decent state of configuration control)

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Relay Identification – Components class vulnerabilities

- Scope of relays assessment is not only relay per se

Device Type	Sensitivity
Auxiliary (Control) Relays (All Subcategories)	Vulnerable
Protective Relays (Unless Otherwise Noted)	Vulnerable
Thermal Overload Relays	Rugged
Solid State Relays w/o Moving Contacts	Rugged
Hand Switches (All Hand-Operated Switches)	Rugged
Limit Switches	Rugged
Torque Switches	Rugged
Position Switches	Rugged
Contactors	Vulnerable
Power Circuit Breakers (Low and Medium Voltage)	Vulnerable
Molded Case Circuit Breakers (MCCBs)	Rugged
Process Switches	Vulnerable
Trip Units w/ Moving Contacts	Vulnerable

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Relay Identification – Contacts

- Even with the simplifying assumptions made above the relay identification task remains a significant effort
  - Relay database at plants are a great benefit bur are rarely available, comprehensive or maintained
  - Walkdowns and drawing mining and assessment is required
- 30,000 contacts identified between relays and frontline equipment
- Contacts list boiled down to 1000/2000 relays.

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Correlations and modeling challenges

- What do we do with 2000 relays and 30,000 contacts?
  - Likely large number of contacts chatter would not result in functional failure of the front-line equipment
  - Without prioritization, functional chatter evaluation (functional screening) of 30,000 contacts becomes a daunting task
- Ideally we would like to use the PRA logic model and prioritization to inform/prioritize which functional analysis to do.

Correlations and modeling challenges

- Initial fragility estimates are performed based on equipment location and available EQ testing reports ➔ An initial HCLPF estimate is provided for each of the 2000ish relays
- Relays are initially grouped based on the initial HCLPF estimate.
- Initial grouping may group relays of different types and in different location
- 2000 relays grouped in up to 40 relay groups with HCLPF ranging from 0.01 to 2+g

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Correlations and modeling challenges

- Each of the initial relay group is potentially mapped to multiple components
  - Logic should be checked for relay groups that become "mutually exclusive" with themselves and are deleted by the solution.
- Computational weight of all these relay groups can be significant for the quantification engines.

Breaking Correlation

- Balancing the number of relay groups is needed to maintain a decent quantification performance (or plainly avoid running out of memory)
- Relay groups modeled as discussed above can be considered as "surrogate".
  - If they do not contribute to the solution the approximation and conservative modeling approach is acceptable
- PRA logic and quantification process guides the breaking of correlation/grouping in a more realistic fashion

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Breaking Correlation

- For relay groups with high importance* correlation is broken based on
  - Location: relays in different physical location (i.e., different enclosure)
  - Relay type
  - Relay mounting or orientation
- After the initial breaking of correlation, important relay groups becomes normally of a decent size (few relays or few combination of relays) ➔ refinement becomes practical

Relay modeling refinement

- Opt. 1 – relay chatter evaluation and functional screening ➔ higher return as the relay is ELIMINATED from the logic
- Opt. 2 – if functional failure is confirmed then the next refinement step is fragility-based
  - Initial fragility estimate may be based on a simplified fragility of the enclosure
  - A much more detailed fragility can be performed for the actual relay
- Opt. 3 – Human Action can be added to reset the relay (if procedurally allowed)

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Conclusions/Lessons Learned

- Relay chatter is a significant effort in a S-PRA
  - Even with needed simplifying assumptions and modeling approaches
- The ongoing more systematic evaluation is resulting in relays being one of the lead contributors in almost all recent S-PRAs.
- Risk-informed approach to model refinement associated with relay impact is needed to keep the problem solvable.
- The Paper provides a number of specific examples of lessons learned associated with:
  - Relays-chatter-induced initiating events
  - Ranking of relationship between relays and front-line equipment failure that may be prioritized
  - Failure modes of interest under a system and fragility basis.
  - Sensitivities associated to specific relay grouping

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Questions?