Transferring Probabilistic Risk Assessment (PRA) Knowledge and Developing PRA Models for a Natural Gas Company

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Abstract: Natural gas companies face significant risks in their operation and maintenance on a daily basis with regionally located assets that are vulnerable to various types of threats. For some of these assets (e.g., piping) there are semi-quantitative risk management programs that provide detailed guidance to prioritize operation and maintenance of the assets, however, performing detailed probabilistic risk assessment (PRA) modeling of these assets is new to the natural gas industry.

Fauske and Associates with Westinghouse Electric Company LLC support provided in depth technical training on PRA quantification methods and tools to develop a core team of analysts at the natural gas company and assist in producing PRA models for several types of natural gas assets.

This paper discusses the process for PRA technology transfer to a natural gas company. It includes observations made of the processes and tools used for this technology transfer between two very different industries.

Keywords: Probabilistic Risk Assessment, Natural Gas, Technology Transfer

1. INTRODUCTION

Probabilistic Risk Assessment (PRA) techniques are widely used in the highly regulated nuclear power industry. Note that in this paper the term PRA is used and is considered the equivalent of probabilistic safety assessment (PSA). Decades of developing and refining nuclear power plant PRA models, and developing industry standards for PRA models, have resulted in the development of tools and programs aimed at assessing nuclear power plant safety, identifying systems, structures, and components (SSCs) vulnerabilities and measures to rank the relative risk of SSCs. The nuclear power plant PRA models are currently being used to manage risk in real time during normal operation and shutdown conditions and optimize plant operation using risk-informed programs focusing on testing, inspection, maintenance and outage programs.

Natural gas companies face significant risks in their operation and maintenance on a daily basis with regionally located assets that are vulnerable to various types of threats. For some of these assets (e.g. piping) there are semi-quantitative risk management programs that provide guidance to prioritize operation and maintenance of the assets. However, pipeline safety administrators increasingly emphasize that quantitative or probabilistic risk models are more versatile and capable of providing risk insights to support decision making. Therefore, quantitative or probabilistic risk modeling is a relatively new application in the natural gas industry.

This paper discusses the process for PRA technology transfer to a natural gas company performed by Fauske and Associates (FAI) supported by Westinghouse Electric Company PRA staff. It includes

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observations made of the processes and tools used for this technology transfer between two very different industries.

2. CONCEPTUAL DISCUSSIONS AND INITIAL ACTIVITIES

The first phase of the PRA technology transfer focused on familiarizing the client leaders with the potential role of PRA technology in managing risks. Initial web-based meetings were held to convey some of the fundamentals of developing PRA models and how they can be used. To make the PRA technology exchange more relevant to the natural gas industry, the client conducted a conference call introducing the types of assets they manage and described some of the programs they currently have in place to address and track challenges to those assets. These activities were followed up by a workshop for the client to present high level PRA fundamental training referencing where possible similarities for natural gas assets based on PRA modeling of nuclear power plant systems. The workshop was presented to a large number of client stakeholders and included dividing the attendees into groups, providing each group with a relevant topic related to their natural gas assets, and having the group to develop a problem statement. Based on the problem statement each group was coached in their selection of a PRA tool to use to investigate the problem. This resulted in the development of rudimentary event trees, fault trees, and failure modes and effects analyses (FMEAs). This portion of the workshop concluded with group presentations on their problem statement, the PRA tool selected to investigate the problem statement, things that worked well with the tool, challenges they had with the tool, and insights on critical risks gained from doing the exercise. The training and workshop provided the client valuable initial insights as to the information that could be gained, the data that would be needed, and the potential uses if PRA models were developed for their assets.

Based on the workshop, discussions with FAI, and discussions with other natural gas industry companies that are incorporating risk assessments into their operations, the client decided to develop PRA knowledge and models for some of their assets. The client wanted to fast-track PRA knowledge and development, so a core team was created and challenged to develop PRA skills and models working with FAI. A four-week training course was developed for the client to transfer PRA knowledge to the core team and work with the core team to develop models specific to the client's assets. The four-week course included training on fundamental PRA concepts such as development of event trees, system analysis to support fault tree development, and supporting skills with a focus on application to the natural gas industry and the client asset classes. Additional support skills included use of PRA tools and strategies for:

- Identification and development of event sequences
- Use of FMEAs to identify system failures
- Data collection methods
- Human reliability assessment
- End state classification

The asset classes for model development were defined as:

- Storage - supplemental gas facilities including liquefied natural gas plants, propane air plants and underground storage facilities.
- Transmission pipelines - pipelines delivering gas from upstream suppliers to distribution systems, typically at pressures ranging from 200 pounds per square inch (psi) to 750 psi and sizes ranging from 12 inches to 30 inches in diameter.
- Distribution pipelines - distribution mains delivering gas from transmission pipelines to customer service lines, typically from pressures ranging from inches water column to 200 psi and sizes ranging from 2 inches to 12 inches in diameter.

- Measurement, Regulations and Control - Facilities that measure gas flows, regulate gas pressures and monitor/control flows and pressures in the distribution system.
- Service Lines and Meters - Facilities are downstream of the meter owned and operated by the customer, including piping, valves, appliance regulators and appliances.

3. TRAINING

Traditionally the development of a well-rounded PRA analyst is a measured and progressive process. For example, a new practitioner is often assigned a mentor who will involve him or her in their ongoing projects. Ideally to ensure that the new practitioner is not overwhelmed the mentor will give them small sub-tasks to allow them to hone their skills on a smaller scale rather than being challenged with a more comprehensive task/project. Therefore, the new practitioner will have a good amount of experience to fall back on and will slowly be introduced to concepts and facets of a PRA over time as experience is gained.

Additionally, when a PRA practitioner becomes proficient in a given area that person will often be given similar tasks to support several projects. For example, if a person becomes familiar with data analysis for one project and then a new project is initiated, the best fit for that analyst will most likely be to work on the data analysis of the new project for several reasons such as less time and supervision required given the increased skill level. Over a long period of time this has the effect of developing the practitioner into a subject matter expert (SME) of a particular skillset such as data analysis as used in this example.

There are advantages and disadvantages of this practice. On one hand the practitioner becomes very proficient in a given skillset but on the other hand they may not be exposed to many other areas of PRA, so their experience level becomes deep but narrow. In addition, if the same analysts perform the same tasks for each project this effect tends to become somewhat global as you have SMEs in each area, but each SME has a narrow range of overall PRA skillsets. To offset this, there is typically a conscious effort made to move people around, when possible, to diversify their experience; especially if there is a vital skillset with limited expertise at the company. Over a long period of time the practitioner will eventually become proficient in multiple areas of PRA and eventually acquire all the skills needed to develop and oversee a fully integrated PRA. The key, as noted above, is that this typically take a *long time*.

For this project FAI was tasked with developing PRA practitioners that would be able to demonstrate a wide variety of PRA skills in a very short timeframe (~3 months). In addition, we also needed to adapt our training process to a completely different industry. This required re-evaluating the level of detail and the applicability of our typical training process to ensure that it was appropriate for this purpose. Also, the course structure needed to be optimized to ensure maximum knowledge retention to allow for the trainees to quickly start model development. The training was broken up into several elements with the first session typically being a presentation followed by a second workshop session where the trainees would utilize the tools and apply them to their industry. This proved to be very effective and a short summary of each session is discussed below.

<u>Initiating Events Analysis:</u> The initial input needed to examine the corresponding risk with PRA tools was discussed. We described the types of things that could apply to the nuclear industry and looked for feedback from the trainees on what types of issues they had experienced. Beyond this, it was noted that that high-risk events may need to be considered even if they have never actually occurred (e.g., Large Loss of Coolant Accident in the Nuclear industry). One major takeaway here was that a leak in the system would account for the majority of events.

Accident Sequence and Success Criteria: The asset response to a particular initiating event was discussed. We walked through the development of event trees that resulted in multiple scenarios playing out depending on the success or failure of the mitigating functions. A major takeaway here was that the natural gas industry assets have very little defence-in-depth. Challenges occurred due to the natural gas assets in which a single failure may result in an undesired end state. Therefore, there were not a series of mitigation systems to prevent the asset from reaching an undesirable end state. This really limits the need for event trees when examining risk in this industry. Discussions on the event tree sequences ending in success or an undesired end state led to the development of the undesired end states that would be considered for the PRA models of the natural gas assets. These undesired end states were leak, loss of service, injury or death, and unknown. The unknown category was for an off normal occurrence in a modeled asset that would affect a different downstream asset.

System Analysis: The need to understand the different assets and how they perform their function was discussed. This resulted in identifying all the components of interest in a particular asset that needed to be evaluated further as well as possible human actions that would need to be analyzed. This was largely facilitated through an FMEA. A major take away here was that the team learned a lot more about the assets and how they function as part of this process.

Data Analysis: Once the components were identified as a result of the FEMA performed as part of the systems analysis workshop, the need to develop data to represent these components in the risk model was discussed. This proved to be somewhat challenging. In the PRA industry there are readily available generic data sources for most components modeled per references such as NUREG/CR 6928 [1]. In addition, there are practices in place to collect plant-specific data for programs such as the Maintenance Rule. It was determined that there were indeed natural gas industry sources for natural gas pipe rupture for the main transmission and distribution lines but for service lines and other components this required more effort for company-specific data. It was noted that there are various sources of international data available (e.g., [2]). Additionally, it was noted that when a test occurred, and a component failed, it would be repaired but a report would not necessarily be generated so there would not likely be a record of the repair.

Human Reliability Analysis (HRA): This was perhaps one of the most difficult areas to translate for a couple of reasons. First, while the concept of pre-initiators was somewhat applicable to the natural gas industry the probability of occurrence was more difficult to assess because often the maintenance activities were not proceduralized but rather were more reliant upon memorized practices. Secondly, what is referred to as a post-initiator in the nuclear industry was quite different as well due to the geographically expansiveness of their assets which were sometimes spread out over hundreds of miles rather than confined to one site with operators on hand. Additionally, many of the assets typically do not have indications or cues to recognize a problem so usually a leak is not discovered until customers call due to loss of service. Even if there were a possibility to mitigate a leak the operator would not likely be onsite when the leak occurred, so diagnosis and response was completely different.

Quantification: Once data was obtained for the example models developed in the previous training sessions we discussed the quantification of the model. Here we discussed the process of assembling several system models into a one top model to represent the accident sequences. This was accomplished by first developing a few simple system models and then collecting them under a developed top logic to demonstrate model integration. Following this the concept of flag files and recovery rules were discussed to allow the manipulation of the model pre-quantification or the model results post-quantification.

This completed the training and demonstration sessions. From this point on the project focused on mentoring the client in the development of models to fit their actual systems as discussed in Section 4. One key takeaway was that results needed to be put into context rather than aggregated given the multiple undesirable end states modelled. For example, a leak (one end state) that causes a loss of service (another end state) would be double counted if those results were aggregated together.

4. MENTORING

Following the transfer of PRA knowledge to the client core team mentoring was incorporated into the plan to assist in the development of probabilistic risk models specific to the client's assets. Critical asset workshops and model builds with direct oversight by experienced FAI PRA practitioners were conducted to begin utilizing the PRA tools and strategies. The FMEAs and fault trees developed during these workshops were reviewed and schedules for model build completion were developed for each asset. With the event sequences and end states determined, emphasis could now be focused on improving the data collection methods and human reliability assessments as key inputs to the modeling efforts.

Mentoring continued to provide support to the client core team through:

a. Remote review of completed draft material
b. Participation in client meetings and status discussions with asset owners
c. Response to logistical and technical questions
d. Guidance on development of input deliverables for the PRA program (Type Codes, Notebooks, Generic Industry Data)
e. Guidance on communicating asset risk across the company

Mentoring also focused on considerations for a more robust, reliable model and a sound foundation for the PRA program that includes:

a. Development/Review of critical operating and maintenance procedures for a system of checks and balances
b. Development of a reliable data collection program
c. Establishment of a strong Safety Culture Program to provide HRA insights
d. Development and institution of Change Management for PRA models

The objective of mentoring is to focus the usage of the PRA model output as a key data input to the client's safety and risk informed decision making process. By focusing on the most critical components, PRA model conclusions can be used to influence financial decisions leading to reduced spending for maintenance or operation of certain equipment or increasing spending on more critical assets (maintenance, testing, procurement, etc.).

5. RESULTS AND CONCLUSIONS

FAI supported by Westinghouse was able to conduct PRA technology transfer and PRA model development mentoring to a natural gas company client on a challenging schedule. To be successful it required a number of PRA experts to provide the training, a dedicated focused client core team, and continued mentoring during asset PRA model development and review by client SME review groups. Challenges encountered included gaining a quick understanding of the natural gas industry assets and the challenges to those assets by FAI, a rapid immersion into PRA fundamentals and model development by the client, defining the appropriate undesired endstates, and choosing the appropriate scope and assets to model that would provide valuable PRA insights as the first step in incorporating PRA techniques into the client's risk management programs.

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