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Development and first application of an operating events ranking tool

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HIGHLIGHTS

- A method using analitycal hierarchy process for ranking operating events is developed and tested.
- The method is applied for 5 years of U.S. NRC Licensee Event Reports (1453 events).
- Uncertainty and sensitivity of the ranking results are evaluated.
- Real events assessment shows potential of the method for operating experience feedback.

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ABSTRACT

The operating experience feedback is important for maintaining and improving safety and availability in nuclear power plants. Detailed investigation of all events is challenging since it requires excessive resources, especially in case of large event databases. This paper presents an event groups ranking method to complement the analysis of individual operating events. The basis for the method is the use of an internationally accepted events characterization scheme that allows different ways of events grouping and ranking. The ranking method itself consists of implementing the analytical hierarchy process (AHP) by means of a custom developed tool which allows events ranking based on ranking indexes pre-determined by expert judgment. Following the development phase, the tool was applied to analyze a complete set of 5 years of real nuclear power plants operating events (1453 events). The paper presents the potential of this ranking method to identify possible patterns throughout the event database and therefore to give additional insights into the events as well as to give quantitative input for the prioritization of further more detailed investigation of selected event groups.

1. Introduction

Like any other mature industry nuclear power plants are using many sources for maintaining and improving the availability and safety. Operating experience is one such source with significant potential. Multiple motives exist to collect, process, and analyze operating events. By analyzing them as a group of similar events it is possible for example to avoid recurring events (Pyy and Ross, 2004), to estimate parameters values for ranking and reliability models (e.g.: component failure rates in Cadwallader and Eide, 2010; human errors in Jang et al., 2013; and initiating events in U.S. NRC, 2007 and U.S. NRC, 2011). Detailed investigation of selected events provides potential to obtain additional valuable insights into failure causes (Viveros et al., 2014) and system behavior (Reventós et al., 2010). Significant challenges are present in every step of the whole cycle of operating experience feedback from events reporting system (Hewitt, 2011) to interpretation and understanding (Ramanujam and Goodman, 2011; Stoop and Dekker, 2012; McCollin and Coleman, 2013; Vinnem, 2013). All these issues are still developing under many activities at different levels: from plant and national to multinational (e.g., International Atomic Energy Agency in IAEA, 2007; and European Clearinghouse in Noël, 2010).

Interesting and potentially valuable questions are (1) how to further improve insights from the complete set of events, i.e. how to identify patterns throughout the complete database which cannot appear through investigation of individual events?; and (2) considering the large number of events and the limited resources available, how can the events investigation and the successive actions be prioritized, i.e. according to which parameter or combination of parameters?

Nuclear Energy Agency Working Group on Operating Experience (NEA WGOE, 2011) is an example of trend analyses considering all events. There are many examples where specially selected events group are analyzed (Schenk et al., 1984; Zerger et al., 2013). These

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and other available studies provide base for the conclusion that there is need to further improve the analysis of the complete set of operational events. This is first to improve learning from complete set of events and second to help better selection of the most important group of events for further more detailed analysis. In Jacobsson et al., 2011 one of six steps for incident learning is "on an aggregate basis" with advantages from doing it before more detailed separate events investigation.

The question is what is required in order to allow such analysis at the level of complete set of events. Ideally database with events descriptions would be sufficient. However, this is not the case because these events were documented with the specific purpose of analysis and not with the perspective of further ranking or specific statistical use. Therefore, additional events characterization seems necessary. After that it is possible to perform events groupings and parameters assessment which will allow quantitative based ranking. By using a comprehensive events characterization scheme, with a quantitative ranking method, it is possible to determine the relative importance for event groups. Both characterization and ranking could be used for the selection of the best candidates for further more detailed investigation and also for some additional events analysis. This approach has potential to fill the assessment gap between the raw data statistical analysis and selected events special investigation. It could be also seen as complementary to the different data mining techniques used to process and analyze accidents (Cheng et al., 2013).

This paper presents the development of the event groups ranking method implemented as a software tool. Demonstration of the analysis applied to the significant set of complete data from real operation is also presented. Applied characterization scheme is based on the internationally known and agreed approach. The presented results are the first application of this approach with a comprehensive characterization scheme on the significant real data set. Šimić et al. (2014a) presents comparison of several alternative ranking methods with limited characterization scheme and different data sets.

The following sections describe the developed event groups ranking method, implemented tool and results from the analysis of 5 years of real data.

2. Event groups ranking method and tool

Operating events are collected as reports, then coded and stored into the database. While reports and related reference documentation are necessary for individual events investigation, a proper coding with an associated event characterization system is needed for events ranking. The ranking of events groups based on selected characteristics has to be quantitative and traceable in order to allow different expert judgments and use of sufficiently broad criteria. These requirements are basis for the development of the characterization scheme and ranking method.

Ranking method is applied to the significant set of real operating events. The best available source is the United States Nuclear Regulatory Commission (U.S. NRC) Licensee Event Reports (LER) because it is an open online database with description of all significant events occurred in any nuclear power plant in the USA (U.S. NRC, 2013). In this analysis it was decided to cover LERs occurred during recent 5 years, starting from 2007. The total number of events in this period was 1453. LERs present roughly about 10% of all events (Revuelta, 2004) which are certainly the most significant. The herein described approach is applicable to any set of events but later described characterization is necessary.

The following subsections describe the ranking method and the developed software tool.

Table 1
List of events and groups parameters used for database and ranking tool.

Parameter	Description (format or number of different values)	Use[a]
Plant	Unique plant designation	S
Vendor	Supplier of the nuclear and steam side	S
Reactor	Reactor type	S
Status	Of the reactor when event occurred (11)	S
Time	Time when event occurred (dd.mm.yy hh:mm)	S
Group	Staff involved, or likely to learn from event (4)	S
Activity	Performed when event occurred or detected (23)	G
Direct cause	Of the event (9)	G
Systems	Malfunctioning, failed, affected and degraded (10)	G3
Components	Malfunctioning, failed, affected and degraded (7)	G3
Root cause/Causal factor	Multiple characterization (22)	G3
Consequences	Caused by event (10)	R3
Category	Broad event categorization (8)	R
Multiple	Number of affected elements or common cause/mode (4)	R
Safety	Estimated conditional safety relevance (3)	R[b]
SD/O ext.	Duration of shutdown or outage caused by event (h)	R
Frequency[c]	Ratio of events in group to total (–)	R
Trend	Change of the events number over several years (–)	R[d]

[a] All parameters are used in Statistical reports (**S**) and some of them are used also for Grouping (**G**) or Ranking (**R**). Number ***3*** means that event could have up to three parameter values (one value is minimum).
[b] Safety relevance is important: it is judged if explicit information in the report is not available.
[c] Frequency is characterizing number of events in the group.
[d] Trend is not an event parameter, but calculated value for the group of events over time.

2.1. Ranking method

The ranking method requires a defined closed scheme for events characterization and a transparent ranking algorithm. The ranking algorithm consists of ranking indexes quantification and their relative importance determination. The relative importance is determined by the use of an analytical hierarchy process (AHP). The final ranking value is determined by the summation of ranking indexes weighted with their respective relative importance.

Details about events characterization and ranking algorithm are the following.

2.1.1. Events characterization

The event characterization system was defined based on the accepted coding format from well-known and respected sources (IAEA International Reporting System, IRS, in Zhang et al., 2011; and Word Association of Nuclear Operators, WANO in Revuelta, 2004) with changes in respect to the total number of possible values and few specific parameters. The total number of possible values for all parameters was reduced in order to optimize grouping and ranking process, i.e. to have enough possible values to allow relevant grouping and ranking and to allow the events to be characterized with a reasonable use of resources and time.

Based on the reference sources and the goal to optimize number of parameters used for events characterization, a final list of parameters is determined and applied to a selected set of US NRC LERs. Table 1 presents all parameters used for events characterization with a total of about 120 parameters values (or attributes). Most of the parameters are used for grouping, i.e. for creating relevant and consistent groups of events which could undergo further analysis,