Overview of the 2017 Revision to IEEE Standard 1082: Guide for Incorporating Human Reliability Analysis into Probabilistic Risk Assessments for Nuclear Power Generating Stations and Other Nuclear Facilities

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Abstract: The Institute of Electrical and Electronics Engineers (IEEE) Standard 1082, a guide which covers human reliability analysis (HRA) for nuclear power applications, was introduced in 1997. While the guide has proven foundational for HRA, many elements of the guide are now commonplace, while the scope and diversity of HRA methods has increased. A working group of 16 HRA experts was convened to review the applicability of IEEE-1082 and determine possible revisions. The working group agreed on the value of reaffirming the guide, because it remains a foundational document that is also uniquely method neutral. The working group revised the guide, including updated references and treatment of contemporary applications of HRA. The revisions to IEEE-1082 were ratified in late 2017, and the revised guide is now available. This paper highlights changes to the guide in the current revision and overviews the approach to integrating HRA into risk assessments. This paper also compares IEEE-1082 to other guidance documents like the Electric Power Research Institute's Systematic Human Action Reliability Procedure (SHARP1), the American Society for Mechanical Engineers standard for probabilistic risk assessment (ASME/ANS RA-Sb-2013), and the Nuclear Regulatory Commission's Good Practices for HRA (NUREG-1792). IEEE-1082 maintains a unique position as a general framework for conducting HRA. While optimized for nuclear power applications, the guide also provides useful guidance for HRA in non-nuclear domains.

Keywords: Human Reliability Analysis (HRA), IEEE-1082, Standard.

1. BACKGROUND ON THE GUIDE

The Institute of Electrical and Electronics Engineers (IEEE), among other functions, serves as one of the world's largest standards organizations through the IEEE Standards Association. Within the IEEE Power and Energy Society (PES), there is the Nuclear Power Engineering Committee (NPEC), whose Subcommittee 5—Human Factors, Control Facilities, and Reliability—is responsible for standards related to human factors in nuclear power applications. Many of the IEEE NPEC standards are co-logoed, adopted, or endorsed by national and international standards organizations and regulators.

In 1997, following several years of development, IEEE introduced IEEE Standard 1082, *IEEE Guide for Incorporating Human Action Reliability Analysis for Nuclear Power Generating Stations* [1]. The terminology of IEEE-1082's title is important. While term "standard" is used throughout this paper, the document is intended as a guide, meaning it is non-binding best practices for HRA. The purpose of this succinct guide was to provide direction on conducting human reliability analyses (HRAs) and incorporating these analyses into probabilistic risk assessments (PRAs).

Since the publication of the seminal *Technique for Human Error Rate Prediction* as NUREG/CR-1278 in 1983 [2] and supporting U.S. and international regulations requiring HRA as part of nuclear power plant licenses, HRA had established itself as an important field, with several new methods developed by the U.S. Nuclear Regulatory Commission (U.S. NRC), the Electric Power Research Institute (EPRI), and international entities. At the same time, these methods presented themselves as competitors to one another. Specific process guidance was limited to methods or textbooks, but there was no standard to guide HRA application across methods. Thus, an important hallmark of the original IEEE 1082 standard was its neutrality to specific HRA methods.

The 1997 standard [1] featured an eight-step generic HRA process as follows:

1. *Select and train team*—this step highlights the importance of assembling the right skills to perform the analysis, typically through an interdisciplinary team.
2. *Familiarize team with plant*—this step involves gathering relevant information about the plant, procedures, crew, etc., to understand human interactions with plant systems.
3. *Build initial plant model*—this step involves characterizing human interactions with the system as part of the PRA.
4. *Screen human interactions*—in this step, the plant model is analysed with the human actions to see the impact of those actions on core integrity. Conservative values are used, and only those human interactions that have an impact are retained in the model.
5. *Characterize human interactions*—this step involves gathering insights on those aspects that shape the human performance and should be considered in quantification.
6. *Quantify human interactions*—in this step, the human error probability (HEP) is calculated using an appropriate HRA technique or method.
7. *Update plant model*—recovery opportunities are considered, and those human interactions that were screened are incorporated back into the PRA model with HEPs, while non risk-significant human interactions are removed from the model.
8. *Review results*—this step serves as a reasonableness check on the resultant HRA as incorporated back into the PRA.

IEEE-1082 emphasizes that these steps should be carefully documented to provide a traceable analysis.

2. H.R.A. DEVELOPMENTS SINCE THE ORIGINAL GUIDE

In the more than twenty years since the appearance of the original IEEE-1082 standard in 1997, there have been numerous and significant HRA developments. While a handful of methods were available in 1997, according to one estimate [3], there are now over 60 HRA methods available. Not all of these methods are considered complete methods that cover all aspects of analysis in IEEE-1082, for there has been an effort to create streamlined approaches focused on particular stages of HRA like quantification [4]. Additionally, there have been task-specific methods like for fire HRA [5] or domain-specific methods like for petroleum [6]. There have been significant efforts toward incorporating more cognitive considerations than were found in earlier HRA methods, e.g., [7], and most contemporary HRA methods now consider a greater range of contextual factors or errors of commission [8]. There have been significant efforts at HRA data collection [9]-[11], and there have been efforts to benchmark HRA methods [12-13]. Dynamic HRA has emerged as a viable approach within HRA [14]. Finally, a number of additional general guidance documents have been published on HRA such at the U.S. NRC's *Good Practices for Implementing Human Reliability Analysis* [15] and the American Society of Mechanical Engineers standard on PRA [16], which includes significant mention of HRA considerations.

3. REVISION PROCESS

IEEE-1082 was due for expiration, reaffirmation, or revision. Given the significant changes in HRA since its original publication, it was determined to convene a group of HRA subject matter experts to determine the appropriate fate of the standard. Had the standard outlived its original purpose and utility? Was there value in keeping the standard? Were changes needed that were more significant than a simple update to the bibliography?

A group of 16 international HRA experts was enlisted to review the then current IEEE-1082 standard. With one dissenting vote, the experts agreed that there was value in maintaining and revising IEEE-1082 as a standard. Experts noted that its method independence was a key consideration, since most guidance on HRA is tied to specific methods. Additionally, it was noted that while the standard indeed mirrored standard practice in the nuclear industry, new domains such as oil and gas do not necessarily have the same risk modelling infrastructure as is found in nuclear energy and would benefit from retention of a general HRA standard as a process reference. Additionally, new HRA applications within nuclear energy such as multi-unit HRA, beyond design basis events, emergency mitigation equipment (i.e., "flex" gear), and digital control rooms would benefit from having a basis document to guide future method development. As a consequence, the utility and value of the standard is as a generic guide to affirm existing practice and guide future method development.

The dissenting vote on retaining the standard expressed the view that newer guidance already surpassed the guidance in IEEE-1082, essentially rendering it obsolete. The remaining subject matter experts felt that such issues could be overcome with a series of minor revisions. Specific areas where revision was indicated included:

- *The need to address dependence.* Dependence can occur in a sequence of human actions when one error contributes to subsequent errors. There was no discussion of dependence in the original IEEE-1082.
- *The need to address errors of commission.* Errors of omission are activities performed that are not prescribed. Much of HRA is derived from failures to complete required tasks, so-called errors of omission. It is relatively easier to address skipping a step in a procedure than to anticipate performing activities that are not in the procedures. Yet, errors of commission are no more infrequent than errors of omission. There was no discussion of errors of commission in the original IEEE-1082.
- *The need to address new applications of HRA.* As already mentioned, the revision to IEEE-1082 should address new applications such as multi-unit HRA, beyond design basis events, flex gear, and digital control rooms. Additionally, although the focus of the standard remains nuclear energy, the guidance should be flexible enough to serve non-nuclear applications.
- *The need to consider the increasing prevalence of hybrid HRA approaches.* Human reliability analysts may perform heterogeneous analyses by enlisting different methods for different needs. For example, one HRA method may address action or execution activities very well, while another method may be required for decision making and cognitive tasks. This mix-and-match approach is, in fact, available in one of the most widely used HRA tools, the EPRI HRA Calculator [17], which is a collection of different methods that may be invoked depending on the analysis problem. There was no discussion of hybrid HRA approaches in the original IEEE-1082.
- *The need to update references.* The normative references included in the original IEEE-1082 standard did not reflect current HRA and should be updated to reflect current developments and practices.

The initial survey of subject matter experts was completed in 2014, and revisions were incorporated into IEEE-1082 by the standards working group and iterated to consensus throughout 2015 and 2016. The revised IEEE-1082 standard [18] was completed and ratified in 2017.

4. REVISION HIGHLIGHTS

In the 2017 revision, the IEEE-1082 working group retained the core approach of the original standard to be brief, method-neutral, and process-oriented. The standard is not meant to displace lengthy method-specific guidance but rather to provide an overview of how HRA should function. The process-oriented nature of IEEE-1082 means it is designed as a guide for the application of HRA. It is not meant as a treatise on the nature or history of HRA or a comprehensive comparison of methods. Rather, it outlines a general process that has proven successful in the practice of HRA in the nuclear industry.

Specific revisions include those mentioned in the previous section regarding dependence, errors of commission, novel applications, hybrid approaches, and updated references. Additional revisions include:

- *Revision of the title.* The new title appends the words “and Other Nuclear Facilities” to the end. This title suffix serves to extend the scope of the guide beyond traditional nuclear power plant installations.
- *Revision of definitions.* Definitions now align with those in other IEEE, ASME, or U.S. NRC guidance documents. Some definitions that applied primarily to theoretical constructs (e.g., cognitive psychological principles) in the original IEEE-1082 have been removed, because they did not support the process-oriented focus of the standard.
- *Expanded scope.* The scope of the document now includes personnel beyond the main control room, automated systems, and beyond design basis events.
- *Discussion of HRA methods.* IEEE-1082 now includes reference to the need to select an appropriate HRA method for the particular analysis problem. This selection could result in a hybrid approach.
- *Clarification of HRA team composition.* The revised standard includes a stronger emphasis on an integrated HRA-PRA team rather than disparate members from specific displines. The standard acknowledges that each HRA role does not need to be filled by a separate person and experts may pay multiple roles during analysis.
- *Discussion of other HRA guidance documents.* IEEE-1082 now acknowledges that there are other commonly used reference documents on HRA. EPRI’s revised Systematic Human Action Reliability Procedure (SHARP1) [19], which is newly freely available, provides good detail on integrating HRA into PRA but does not cover the some of the HRA process in as much detail as does IEEE-1082. The ASME PRA standard [16] emphasizes quality requirements but not overall HRA. Moreover, it emphasizes quantification but does not explain qualitative aspects of the analysis that are covered in IEEE-1082. Finally, the U.S. NRC’s *Good Practices for Implementing Human Reliability Analysis* [15] does not provide an overall process flow for HRA. This framing of IEEE-1082 relative to other guidance documents helps establish its roles as a complementary document.

5. CONCLUSIONS

In summary, the 2017 revision of IEEE-1082 updated the two-decade old standard to include current practice, terminology, and references for incorporating HRA into PRA. The applicability is not limited solely to PRA, however, and it provides a vetted, general process by which to conduct HRA. The guide represents a consensus document on best practices for HRA without aligning to specific HRA methods or philosophies. IEEE-1082 remains an important basis document for HRA, and the revisions to the standard support future developments in HRA by generalizing the approach across new domains and applications.

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References

[1] IEEE. (1997). IEEE Guide for Incorporating Human Action Reliability Analysis for Nuclear Power Generating Stations, IEEE Std 1082-1997. New York: IEEE Standards Association.

[2] Swain, A.D., & Guttman, H.E. (1983). Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications. Final report, NUREG/CR-1278. Washington, DC: US Nuclear Regulatory Commission.

[3] Bell, J., & Holroyd, J. (2009). Review of Human Reliability Assessment Methods, RR679. Buxton, UK: Health and Safety Executive.

[4] Gertman, D., Blackman, H., Marble, J., Byers, J., & Smith, C. (2005). The SPAR-H Human Reliability Analysis Method, NUREG/CR-6883. Washington, DC: US Nuclear Regulatory Commission.

[5] EPRI & U.S. NRC. (2012). EPRI/NRC-RES Fire Human Reliability Analysis Guideline, Final Report, NUREG-1921. Washington, DC: U.S. Nuclear Regulatory Commission.

[6] Bye, A., Laumann, K., Taylor, C., Rasmussen, M., Øie, S., van de Merwe, K., Øien, K., Boring, R., Paltrinieri, N., Wærø, I., Massaiu, S., & Gould, K. (2017). The Petro-HRA Guideline. Halden: Institute for Energy Technology.

[7] Whaley, A.M., Xing, J., Boring, R.L., Hendrickson, S.M.L., Joe, J.C., Le Blanc, K.L. and Morrow, S.L. (2016). Cognitive Basis for Human Reliability Analysis, NUREG-2114. Washington, DC: U.S. Nuclear Regulatory Commission.

[8] Boring, R.L. (2007). Dynamic human reliability analysis: Benefits and challenges of simulating human performance. In T. Aven & J.E. Vinnem (Eds.), Risk, Reliability and Societal Safety, Volume 2: Thematic Topics. Proceedings of the European Safety and Reliability Conference (ESREL 2007), pp. 1043-1049. London: Taylor & Francis.

[9] Hallbert, B., Boring, R., Gertman, D., Dudenhoeffer, D., Whaley, A., Marble, J., & Joe, J. (2006). Human Event Repository and Analysis (HERA) System: Overview, NUREG/CR-6903, Vol.1, Washington, DC: US Nuclear Regulatory Commission.

[10] Chang, Y.J., Bley, D., Criscione, L., Kirwan, B., Mosleh, A., Madary, T., Nowell, R., Richards, R., Roth, E.M., Sieben, S., & Zoulis, A. (2014). The SACADA database for human reliability and human performance. Reliability Engineering and System Safety, 125, 117-133.

[11] Kim, S., Kim, Y., Choi, S., Park, J., & Jung, W. (2017). Design and implementation of HuREX analysis supporting interface. Proceedings of the American Nuclear Society Nuclear Power Instrument, Control, and Human-Machine Interface Technology Conference, pp. 516-522.

[12] Lois, E., Dang, V.N., Forester, J., Broberg, H., Massaiu, S., Hildebrandt, M., Braarud, P.Ø., Parry, G., Julius, J., Boring, R., Männistö, I, and Bye, A. (2009). International HRA Empirical study—Phase 1 Report, Description of Overall Approach and Pilot Phase Results from Comparing HRA

Methods to Simulator Performance Data, NUREG/IA-0216, Vol. 1. Washington, DC: US Nuclear Regulatory Commission.

[13] Forester, J., Liao, H., Dang, V.N., Bye, A., Lois, E., Presley, M., Marble, J., Nowell, R., Broberg, H., Hildebrandt, M., Hallbert, B., & Morgan, T. (2016). The U.S. HRA Empirical Study: Assessment of HRA Method Predictions Against Operating Crew Performance on a U.S. Nuclear Power Plant Simulator, NUREG-2156. Washington, DC: U.S. Nuclear Regulatory Commission.

[14] Mosleh, A., & Chang, Y.H. (2004). Model-based human reliability analysis: Prospects and requirements. Reliability Engineering and System Safety, 83, 241-253.

[15] Kolaczkowski, A., Forester, J., Lois, E., & Cooper, S. (2005). Good Practices for Implementing Human Reliability Analysis, Final Report, NUREG-1792. Washington, DC: U.S. Nuclear Regulatory Commission.

[16] AMSE. (2013). Addenda to ASME/ANS RA-Sb–2013, Standard for Level 1/Large Early Release Frequency Probabilistic Risk Assessment for Nuclear Power Plant Applications, ASME/ANS RA-Sb-2013. New York: ASME.

[17] EPRI. (2014). HRA Calculator Version 5.1, EPRI 3002003149. Palo Alto: EPRI.

[18] IEEE. (2017). IEEE Guide for Incorporating Human Reliability Analysis into Probabilistic Risk Assessments for Nuclear Power Generating Stations and Other Nuclear Facilities, IEEE Std 1082-2017. New York: IEEE Standards Association.

[19] Wakefield, D.J., Parry, G.W., Hannaman, G.W., & Spurgin, A.J. (1992). SHARP1: A Revised Systematic Human Action Reliability Procedure, EPRI TR-101711. Palo Alto: EPRI.