Introduction of a research project on development of accident management support tool for BNPP (WWER-1000) based on the lessons learned from Fukushima accident

M. Saghafi, M. B. Ghofrani

Department of Energy Engineering, Sharif University of Technology, Tehran, Iran
saghafi@energy.sharif.edu, ghofrani@sharif.edu

1. Introduction

Following Three Mile Island (TMI) accident in 1979, first severe accident (SA) in Nuclear Power Plants (NPPs), Accident Management Support Tools (AMSTs) were developed and installed in a number of NPPs. Lessons learned from Fukushima accident highlighted importance of Accident Management (AM) in mitigation severe radiological consequences after a SA and suggested reconsiderations of AM program which in turn created the need for AMSTs adaption and modernization. It is predicted that AMSTs will be subject to further developments, inter alia to cover low power and shutdown states as well as normal operation. Furthermore, hydrogen production and related systems in both reactor and spent fuel pool (SFP) are required to be considered in new AMSTs design.
MARS (Raines et al., 1993), ADAM (Zavisca et al., 2002), CAMS (Vayssier et al., 2006) and SAMEX (Park and Ahn, 2010) are examples of AMSTs. There is lack of AMSTs for WWER-1000 NPPs in comparison to the other western type NPPs. While special safety systems for mitigation of severe accidents are foreseen in new designs of WWER-1000, in older designs, accidents are mainly managed by design based safety systems such as relief valves of pressurizer or steam generators (D'Auria et al., 2008). Therefore, there is a need for development and use of AMSTs for WWER-1000, especially for older designs.

2. Lessons learned from Fukushima accident

Similar to the lessons learned from Chernobyl and TMI accidents, the lessons learned from Fukushima accident were investigated and published, in which lessons related to accident management have considerable share. Modification in accident management program and related safety systems, which can generally affect the design and applications of AMSTs, are summarized as follows:

- An active tsunami warning system should be established with the provision for immediate operator action (IAEA, 2011); With early notification of external natural hazards, AM measures can be planed using predictions of AMSTs,
- For severe situations, such as total loss of off-site power or loss of all heat sinks or engineering safety systems, simple alternative sources for these functions including any necessary equipment should be provided for Severe Accident Management (SAM) (IAEA, 2011); These alternatives should be considered in the design of AMSTs with sufficient flexibility to support decision making,
- Emergency response centers should have access, as far as practicable, to essential safety related parameters (IAEA, 2011); AMSTs ,which are placed in emergency response centers, can benefit from continuous feed of such important information, using its tracking capabilities, to update its prediction and decision support.
- Accident response environment should be improved (Headquarters, 2011) to enhance main and emergency control rooms habitability as well as the feasibility of accident management measures (ENSREG, 2012); AMSTs can be used for longer time to support operator decision making even in severe core damage conditions.
- Instrumentation to identify status of the reactor and containment should be enhanced (Headquarters, 2011) to enable them to effectively function even in SA conditions; AMSTs can benefit from such instrumentations to track events and update status of the reactor and the containment even in late phases of SAs,
- AM measures should thoroughly cover accident progress path (Headquarters, 2011); or in other words onsite emergency response capabilities such as EOPs, SAMGs and extensive damage mitigation guidelines should be strengthen and integrated (Miller et al., 2011); This requires that capabilities of the decision support part of AMSTs be improved enabling them for integrated emergency response,
- Insights about hydrogen control and mitigation inside containment or other buildings should be identified (Miller et al., 2011); Combustible gas phenomena and related safety systems, such as passive autocatalytic recombiners or igniters, can be included in the design of AMSTs for planning containment related AM measures,
- SFP makeup capability and its instrumentation should be enhanced (Miller et al., 2011); SFP model and its instrumentation should be added to the related parts of AMSTs for integrated AM in the reactor, containment and SFP, and
- Improvements with regard to decision making and consideration of the use of tools to support decision making in emergency response; Decision making schemes to support actions for SAM situations should be developed (IAEA, 2013).

3. The proposed method for AMST design

An efficient AMST should have the following principal capabilities (IAEA, 2003): (1) Identification of accidents and diagnosis of the plant damage state (PDS), (2) Prediction of accident progress path and (3) Source term analysis and prediction of radioactive material release. Also it should have an interactive interface for effectiveness assessment of AM measures in short time. Such a tool can therefore be used for planning measures to mitigate core damage and radioactive materials release.
Structure of the proposed AMST includes the following parts: (1) Tracker, (2) Predictor and (3) Decision Support. Simplified relation between parts of the AMST is shown in figure 1. Identification of accident initiator and the plant state are the tasks defined for 'Tracker'. Neuro-Fuzzy networks, a kind of soft computing techniques, is employed for accident identification. The proposed method to develop a modular accident identifier is shown in figure 2. In case of postulated breaks, NARX (Nonlinear Auto Regression with eXogenous inputs) is also used for break size estimation. The Predictor is designed for prediction of accident progress path. MELCOR code is used as a computational engine in Predictor, to provide with most probable phenomena, events timing and source term evaluation. The last part of AMST, Decision support, is conceived to support decision making in selection of AM measures and their implementation times. It has interactive interface with the plant operators for effectiveness assessment of CHLAs. A rule-based Expert System with a mixed chaining reasoning algorithm is employed in the structure of 'Decision support' to compare positive and negative effects of the selected CHLAs.

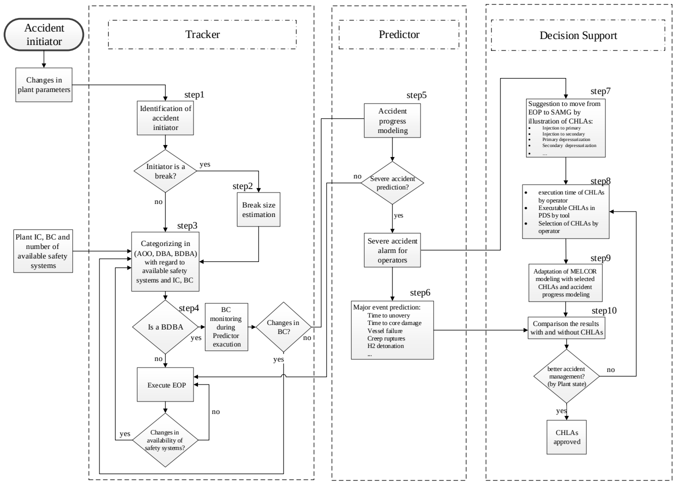

Figure 1- Structure of the proposed AMST for BNPP

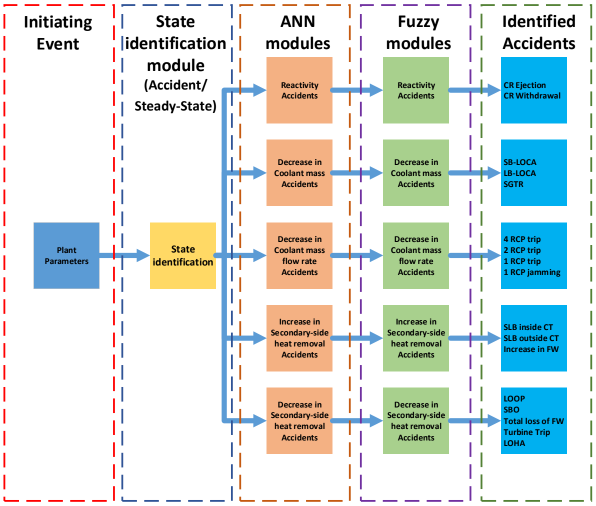

Figure 2 – Detail Structure of accident identifier for tracker of AMST

4. Conclusion

In this paper, a comprehensive literature review is conducted, in order to summarize and the lessons learned from Fukushima accident which are related to AM program and can generally affect the design and application of AMSTs. Consequently, an innovative design for an efficient AMST for Bushehr Nuclear Power Plant (BNPP) is proposed. Fast response, high accuracy, easy to use and interactive features are main characteristics of an efficient AMST. AMSTs can provide vital information about the plant states, e.g. timing of critical events, severe AM entry time and quantitative estimation of important parameters. Such information cannot be provided by typical Severe Accident Management Guidelines (SAMGs) due to their dependency to the plant initial and boundary conditions. Early prediction of the plant parameters can provide wider time window for selection of Candidate High Level Actions (CHLAs) while enabling NPP operators better understanding of the accident progress path.

5. References

D'Auria F., Suslov A., Muellner N., Petrangeli G., Cherubini M., (2008), Accident Management in VVER-1000. Science and Technology of Nuclear Installations 2008.
ENSREG s.t.p.r.b.o.e.n.s.r.g., (2012), Post-Fukushima accident peer review report, Stress tests performed on European nuclear power plants.
Headquarters N.E.R., (2011), Report of Japanese government to the IAEA ministerial conference on nuclear safety-The accident at TEPCO's Fukushima Nuclear Power Stations, Government of Japan.
IAEA, (2003), Application of simulation techniques for accident management training in nuclear power plants. International Atomic Energy Agency, Vienna.
IAEA, (2011), IAEA international fact finding expert mission of the Fukushima Dai-ichi NPP accident following the great east japan earthquake and tsunami, Japan.
IAEA, (2013), International Experts Meeting on Human and Organizational Factors in Nuclear Safety in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant, Vienna, Austria.
Miller C., Cubbage A., Dorman D., Grobe J., Holahan G., Sanfilippo N., (2011), Recommendations for Enhancing Reactor Safety in the 21st Century: The near-Term Task Force Review of Insights from the Fukushima Dai-Ichi Accident. U.S. Nuclear Regulatory Commission.
Park S.-Y., Ahn K.-I., (2010), SAMEX: A severe accident management support expert. Annals of Nuclear Energy 37, 1067-1075.
Raines J., Hammersley R., Henry R., Blaisdel J., Bonaca M., Khalil Y., (1993), MARS–An Accident Management Tool, Specialist Meeting on Simulators and Plant Analyzers (Proc. Symp. Lappeenranta, 1992), VTT-SYMP-141, NEA/CSNI.
Vayssier G., Fantoni P., Borondo L., Martinez R., Krajnc B., Dessars N., Husarcek J., Bahna J., (2006), A perspective on computerized severe accident management operator support SAMOS, ANS Annual Meeting, Reno, Nevada.
Zavisca M., Khatib-Rahbar M., Esmaili H., Schulz R., (2002), ADAM: An Accident Diagnostic, Analysis and Management System—Applications to Severe Accident Simulation and Management, 10th International conference on nuclear engineering. American Society of Mechanical Engineers, pp. 131-136.

Poster ID Number: 75
IEM on Strengthening Research and Development Effectiveness in the Light of the Accident at the Fukushima Daiichi Nuclear Power Plant,
IAEA Headquarters, Vienna, Austria, 16–20 February 2015