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

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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 recommissioning 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 reactors and spent fuel pool (SFP) are required to be considered in future AMSTs' design. MARS (Raines et al., 1993), ASBO (Zavata 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 were devised 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 techniques and 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, measures can be planned 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 passive safety systems 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 AMSTs functionality and emergency control rooms' capabilities 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,
- AMSTs 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 strengthened and integrated (Müller et al., 2011); This requires the 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 (Müller et al., 2011); Combustible gas phenomena and related safety systems, as passive automatic 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 (Müller et al., 2011); SFP model and its instrument 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 module, a kind of soft computing technique, 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 predict with most probable phenomena, events timing and source term evaluation. The last part of AMST, Decision support, is conceived to support decision making in AMSTs, a kind of soft computing technique, is employed for 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 support decision making and negative effects of the selected CHLAs.

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
Nuclear Power Plant, Vienna, Austria.