Recent Perspective on the Severe Accident Management Programme for Nuclear Power Plant

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1. INTRODUCTION

Severe Accident Management Guidelines (SAMGs), has been developed to help operators to prevent or mitigate the impacts of accidents at nuclear power plants. Severe accident management was first introduced in the 1990s with the creation of SAMGs following recognition that post-Three Mile Island Emergency Operating Procedures (EOPs) did not adequately address severe core damage conditions.

However, following the accident at the Fukushima Daiichi nuclear power plant in March 2011, it was highlighted the importance of ensuring that systems for the prevention and mitigation of accidents are separate and independent to the extent practicable for assuring an effective defence-in-depth (DID). Establishing and maintaining multiple layers of defence against any internal/external hazards is an important measure to reduce radiological risks to the public and environment.

Moreover, the global nuclear community requests reliable accident management capabilities to deal with extreme internal/external hazards at nuclear power plants. In order to establish realistic and enhanced accident management guidelines, it is fundamental to promote sharing of the best current practices confirming the effectiveness of severe accident management guidelines. Therefore, there is recognition to a need to update current relevant IAEA Safety Standard No. NS-G-2.15 on *Severe Accident Management Programmes (SAMP) for nuclear power plants* with lessons learned from Fukushima accident experience. Therefore, the revised Safety Guide (DS483) added lessons learned from Fukushima accident experience because it was found there are some gaps with existing NS-G-2.15. This revised Safety Guide is intended primarily for use by operating organizations of nuclear power plants and their support organizations. It may also be used by national regulatory bodies and technical support organizations as a reference for developing their relevant safety requirements and for conducting reviews and safety assessments for SAMP including SAMG. The new revised Safety Guide extends its guidance to core/debris cooling, removal of decay heat and long-term cooling, and maintaining containment integrity. Additional challenges are also considered on cooling with non-qualified sources, run-off of contaminated water, threats from the spent fuel cooling, and large-scale natural events at multi-unit sites. Shutdown conditions are also considered. It includes conditions where command and control for the event have been lost, where there is large-scale damage on the site, where major safety functions such as control of reactivity, removal of heat from the core and from spent fuel, confinement of radioactive material.

In parallel with the revision of NS-G-2.15, the Pressurized Water Reactor Owner's Group (PWROG) is also initiating process to upgrade the original generic Severe Accident Management Guidelines (SAMGs). This upgrade includes a Phase I, completed in January 2013, and a Phase II, to be completed in December 2013. In Phase I, the three original Pressurized Water Reactor (PWR) vendor SAMGs in use (i.e., Babcock and Wilcox, Combustion Engineering and Westinghouse) were each upgraded to include those Nuclear Regulatory Commission (NRC) Fukushima lessons learned that could be included. The purpose of updating the SAMGs is to ensure that they benefit fully from Severe Accident (SA) mitigation lessons learned from the Fukushima accident as well as incorporating the latest knowledge of SA phenomenology obtained from research performed since the original SAMGs were developed. The following information on the Fukushima accident is adapted

2. SAMP/SAMG UPDATE

2.1 Revision of NS-G-2.15

The revision of NS-G-2.15 will also provide guidance supporting the proposed new revised requirements. Taking into account the lessons learned from the accident at Fukushima Daiichi NPPs.

Objective and scope

The objective of this Safety Guide is to provide practical guidance and recommendations for the development of an accident management programme as defined in relevant requirement in GSR Part 4, SSR-2/1 and SSR-2/2 aimed at preventing and/or to mitigating the consequences of design extension conditions for beyond design basis accidents and severe accidents. In addition, it is also considered to be managed for accidents resulting from events or combination of deficiencies not considered in the design basis, including external events.

In addition this Safety Guide will address preparation, development, implementation and review of accident management programs for the development of a severe accident management programme. The recommendations of this Safety Guide will be developed for severe accident management during all operating conditions for both reactor and spent fuel pool.

This guideline will also contain guidance on drills / exercises. It will give guidance on how such measures should be defined and how they should be executed to support harmonization of methods used by Member States. It comprises the main elements for accident management in a complete and consistent way with current NS-G-2.15. It is applicable for all Light Water Reactors (LWRs) (e.g. PWR, BWR and VVER) and Pressurized Heavy Water Reactors (PHWRs), but its basic philosophy and approach are anticipated to remain valid for other reactors such as Russian High Power Channel-type Reactor (RBMK).

Therefore, this Safety Guide is intended primarily for use by operating organizations of nuclear power plants, utilities and their support organizations to assist implementation of the severe accident management programme, but also is useful for regulatory bodies to prepare the relevant national regulatory requirements. Furthermore, this guide is also useful for other national organizations involved in emergency response planning and preparedness.

Feedbacks on the accident in Fukushima Daiichi NPPs

Additional inputs on lessons learned from Fukushima Daiichi accident have also been provided by Consultancy Meeting for revision of NS-G-2.15 held on May 2013 for updating more information as following Fukushima lessons learned:

(1) Accident management guidance should be developed and maintained based on the plant design, available internal and external PSA insight (if available), and current industry management guidance. Deviations from plant design requirements and industry standard accident management guidance should receive a rigorous technical and safety review that considers the basis of the original standard and the potential unintended consequences of deviating from this standard.

(2) Accident management guidance should be designed to assist emergency response personnel prioritize, monitor, and execute critical response actions in the working conditions that may exist following an extreme external event.

(3) Accident management guidelines should be developed for establishing core cooling and critical monitoring functions if direct current (DC) power is lost during a prolonged loss of all alternating current (AC) power. These strategies should serve to prevent core damage, if possible, and to mitigate the extent of damage and reduce the potential for a large off-site release of radioactive materials.

(4) For strategies that rely on portable equipment to control key safety functions following an extended loss of all AC power, steps should be taken to ensure that personnel can install and operate the portable equipment within the time frames necessary to avoid loss of key safety functions or extend the coping time during extreme environmental and other post event conditions.

(5) Equipment required to responding a long-term loss of all AC and DC power and loss of the ultimate heat sink should be conveniently staged, protected, and maintained such it is always ready for use if needed.

(6) Procedures for venting containment should be developed assuming normal AC and DC power supplies and air systems are not functional. If rupture disks are installed in vent lines that would inhibit venting when required, a means should be established for operators to manually open the rupture disk or to establish an alternate means of venting the containment.

(7) Plans should be established for relocating personnel as well as communication and coordination functions to alternate locations should normal emergency response facilities be rendered inoperable during an event.

(8) Personnel who direct emergency response shall have the authority to take necessary actions to mitigate the event such as venting containment or injecting seawater or other water sources into the reactor without the need for external authorization. If local regulations require external authorization for such actions, actions should be taken to gain concurrence in advance on criteria for which these actions may be authorized.

(9) Personnel responsible for performing emergency response duties should be trained with the required knowledge skills, and proficiency to execute their roles.

(10) Plans for staffing emergency response positions (including control room operators, site and corporate emergency response centres) for long-duration events shall be developed, maintained, and tested. Staffing plans shall address that the event involves more than one unit at a multi-unit site.

(11) Plants should develop plans to address family/personal needs of responders who are unable to leave the site.

(12) Equipment required to responding a long-term loss of all AC and DC power and loss of the ultimate

heat sink should be conveniently staged, protected, and maintained such it is always ready for use if needed.

(13) Certain key indicators of plant conditions provided erroneous information (e.g., reactor vessel water level) that led the operators to take inappropriate actions. There are two direct lessons from this:

- The operators did not use other available information to validate the information that they used to make decisions.
- The errors in the instrumentation could have been known through analysis; it should have been recognized that reference legs for level instrumentation might boil.
- There was a delay in obtaining instrument indications due to the loss of all power. Even when portable batteries were used, only key instrumentation was powered.

(12) Accident management program was developed from BWROG generic materials but there was only limited sharing of experience with usage outside of Japan. This led to inadequate guidance in certain areas such as instrumentation and command and control.

- Accident management programs should be periodically review by an international team of accident management experts and deficiencies addressed in a timely manner.
- Deviations from accepted international guidance (e.g., Owners Group SAMG) should be documented.
- The SAMG needs to reflect the current plant design and operation - as changes to plant design are made; changes to SAMG also need to be made.

(14) Emergency response relied upon offsite support but in a wide spread natural disaster, offsite support may be delayed.

- Guidance should be developed to address priorities and contingencies for offsite support.

(15) Leadership and response under extreme duress was heroic but not systematically planned in advance. Exercise and drill focus on routine emergencies rather than catastrophic emergencies where all planned resources are not available.

- Leaders need to be chosen based on ability to lead under catastrophic conditions where planned capabilities are not available.

2.2 PWR SAMG

The purpose of updating the SAMGs is to ensure that they benefit fully from Severe Accident (SA) mitigation lessons learned from the Fukushima accident as well as incorporating the latest knowledge of SA phenomenology obtained from research performed since the original SAMGs were developed. The PWROG is updating the SAMGs in two phases.

(a) Phase I PWROG SAMG Update

Phase I implemented the lessons learned from the Fukushima accident, as reflected in the Electric Power Research Institute (EPRI) updated SAMG Technical Basis Report (TBR). These changes include:

- Spent Fuel Pool
- Auxiliary Building(s) (AB) Ventilation
- Use of Raw Water (e.g., sea water, brackish water and river water)
- Modification to Containment Venting Strategies
- External Cooling of the Reactor Vessel Lower Head

(b) Phase II PWRORG SAMG Update

The Phase II portion of SAMG update includes developing generic PWR Severe Accident Management Guidance or PWR SAMG. The PWR SAMG will be applicable to all three PWR vendor designs (i.e., B&W, CE and Westinghouse). The new PWR SAMG includes a number of enhancements, not in the present individual sets of guidance that will make the PWR SAMG more comprehensive by increasing both its scope and level of detail. This, in turn, will increase the robustness of the guidance for diagnosing, managing and mitigating a SA. These enhancements include:

- Best practices from each of the existing three vendor specific SAMGs
- Best practices from the Boiling Water Reactor Owner's Group (BWROG) SAMG
- Increased level of detail as requested by the PWROG
- Feedback from drills and exercises based on the existing SAMGs, including:
    - Simplification of some knowledge based decisions
    - Elimination of points of paralysis in evaluations and decision making
    - Reduce human burden
    - Provide a coordinated "SA Mitigation Team"
    - Provide Main Control Room (MCR) guidance for when a SA occurs and TSC is not activated
- Guidance for a SA originating from plant shutdown conditions
- Guidance for events that affect multiple units on one site
- Additional Guidance for the decision-maker
- Enhanced integration with other accident management procedures and guidance, including:

- Well-defined transitions from Emergency Operating Procedures (EOPs) to the PWR SAMG
- Transitions between the PWR SAMG and Extensive Damage Mitigation
- Guidelines (EDMGs) and Diverse and Flexible Coping Strategies (FLEX) o Common handbook of accident management capabilities
- Reference to existing procedures and guidance for implementing PWR SAMG strategies

(c) Guidance for the MCR and the TSC

The PWR SAMG format will be step-wise providing guidance for both the MCR and the engineering staff in the TSC. The PWR SAMG will follow a command and control structure currently used at PWRs and will be the only accident management guideline in use, although other procedures and guidance may be used to implement SA mitigation strategies.

MCR Guidance

The PWR SAMG is applicable to all situations in which a SA is occurring as indicated by guidance in EOPs or other applicable procedures. This guidance will direct the MCR to enter the PWR SAMG and initiate SA mitigation identified as Severe Accident Control Room Guidance (SACRG).

On entry into the PWR SAMG, the MCR will execute the following vendor preferred priority actions:

(a) Inject water into the steam generators,
(b) Depressurize the RCS,
(c) Inject water into the RCS, and
(d) Inject water into containment.

If the TSC is not activated, at the time the priority actions are completed by the MCR, then the MCR will initiate execution of rule based SA mitigation guidance. This guidance is executed based on easily interpreted parametric information and requires no prior evaluation. The guidance associated with this rule based method is based on quenching and cooling the overheated core, maintaining fission product boundaries and minimizing offsite dose releases.

TSC Guidance

Based on feedback from the PWROG, improvements over the original SAMG have been made in the consolidated PWR SAMG. Most notably, ambiguities associated with TSC evaluation and decision making have been reduced by addition of:

- Increased evaluation bases scope and level of detail (evaluation aid)
- Vendor priorities and preferred methods (reduces evaluation tasks)
- Benefit-Consequence Table (evaluation aid)
- Rapid Decision Matrix (provided to reduce procrastination of decision making)
- Streamlining guidance through its integration such that the guidance is contiguous without the need for flow path transfers to non-contiguous guidance (reduces human burden and its potential for error)
- Simplified CA usage (expedites use of CAs and the potential for error)

(d) PWR SAMG Integration

The original Westinghouse SAMG included a Severe Challenge Status Tree (SCST), used for diagnosis, and associated Severe Challenge Guides (SCGs). In keeping with this concept, the SCGs have been subsumed into their relevant SAGs (e.g., Reduce Fission Product Releases and Reduce Containment Hydrogen). This allows guidance within the relevant SAG to continue by outlining more actions until all possible actions are taken. Thus, the SCST and SCGs are unnecessary since their guidance would be transferred to the relevant SAG as continuous mitigating actions.

Having a single diagnostic tree (i.e., the DPG) that serves the same prioritization function as both the DFC and SCST would be an improvement with regards to human factor error potential during SA mitigation. Additionally, since the actions in the SAGs and SCGs are often the same, the PWR SAMG consolidates appropriate SAGs and SCGs into a single set of guidelines governed by a single diagnostic process. The new diagnostic process will set a prioritization of the parameters and assign multiple color-coded thresholds for a given parameter to determine when a severe challenge is identified. Therefore, a single set of guidelines referenced from a single diagnostic process can reduce the potential for confusion in the TSC as to which guideline to follow.

3. CONCLUSIONS

This study is intended to suggest future regulatory perspectives to strengthen the prevention and mitigation strategies for severe accidents by review of the current status of revision of IAEA Safety Standard on Severe Accident Management Programmes for Nuclear Power Plants and the combined PWR SAMG. This new IAEA Safety Guide will address guidelines for preparation, development, implementation and review of severe accident management programs during all operating conditions for both reactor and spent fuel pool. This Guide is used by operating organizations of nuclear power plants and their support organizations. It may also be used by national

regulatory bodies and technical support organizations as a reference for developing their relevant safety requirements and for conducting reviews and safety assessments for SAMP including SAMG.

The Pressurized Water Reactor Owner's Group (PWROG) is upgrading the original generic Severe Accident Management Guidelines (SAMGs) into single Severe Accident Guidelines (SAGs) for the PWR SAMG aims to consolidate the advantages of each of the separate vendor severe accident (SA) mitigation methods. This new PWROG SAGs changes the SAMG process to be made that can improve SA response. Changes have been made that guidance is available for control room operators when the TSC is not activated thus allowing for timely accident response. Other changes were made to the guidance that will be used in the TSC (or Emergency Response Facility) that will minimize paralysis in evaluations and decision making by providing clear guidance and decision making tools.

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