New regulatory guide for nuclear power plants in Japan after the Fukushima accident

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Abstract: This paper introduces the new regulatory guide for nuclear power plants in Japan, which the Nuclear Regulation Authority (NRA) developed based on lessons of the Fukushima accident. The new regulatory guide consists of three parts: earthquakes and tsunamis; design basis; and severe accident measures. The design basis regulatory guide (including seismic design) is strengthened from the existing regulatory guide based on the lessons from the Fukushima accident. Before the accident, the former Nuclear Safety Commission (NSC) studied the severe accidents and recommended the utilities work on accident management voluntarily. After the accident, the former Nuclear and Industrial Safety Agency (NISA) listed 30 safety measures that should be reflected in future regulation. Following these processes, the NRA prescribed the new severe accident measures on July 8, 2013. It subsequently initiated safety reviews to determine whether to allow the start-up of nuclear power plants forced to shutdown after the Fukushima accident according to this regulatory guide.

Keyword: regulatory guide; design basis; severe accident measures; Fukushima accident

1 Introduction

This paper introduces the new regulatory guide for nuclear power plants in Japan, which the Nuclear Regulation Authority (NRA) developed based on lessons of the Fukushima accident. The draft of this regulatory guide was submitted on February 7, 2013. A lot of opinions about this draft (the reliability of the off-site power supply, the criterion of dislocations, fire protection measures, anti-terrorism measures *etc*.) were entered in the public comment. Following this, experts of the NRA discussed opinions related to the safety of nuclear power plants (NPPs) in their review meetings and revised a part of the regulatory guide. After these processes, the new regulatory guide was prescribed formally on July 8, 2013. The NRA then initiated safety reviews to determine whether to allow the start-up of NPPs forced to shutdown after the Fukushima accident according to this regulatory guide.

Before the Fukushima accident, the former Nuclear and Industrial Safety Agency (NISA) undertook the safety review of NPPs according to the regulatory guidelines that were prescribed by the Nuclear Safety Commission (NSC) and authorized the construction permits and the operational safety programs of NPPs with the agreement of the NSC. After the Fukushima accident, the government judged that this regulatory system was one of the causes that was unable to prevent the accident. It therefore abolished the NSC (*i.e.* the advisory committee) and installed the NRA that has the power to permit and approve NPPs. In addition, the government installed its secretariat that replaces the role of the NISA. Along with the change of regulatory system, the NRA intended to revise existing regulatory guidelines or prescribe new regulatory guidelines in order to judge whether it was appropriate to start-up and continue operation of NPPs based on the results of the safety reviews according.

The second section of this paper introduces the basic policy of the NRA in developing the new regulatory guide. The new regulatory guide consists of three parts as shown Fig. 1: earthquakes and tsunamis [1]; design basis [2]; and, severe accident measures [3]. The design basis regulatory guide, including seismic design, is strengthened from the existing regulatory guide based on the lessons of the Fukushima accident. Before the accident, the NSC studied severe accidents and recommended the utilities work on accident management voluntarily [4]. After the accident, the NISA listed 30 safety measures that should be reflected in future regulation (hereafter “30 safety measures”) on March 28, 2012 [5]. As a result,

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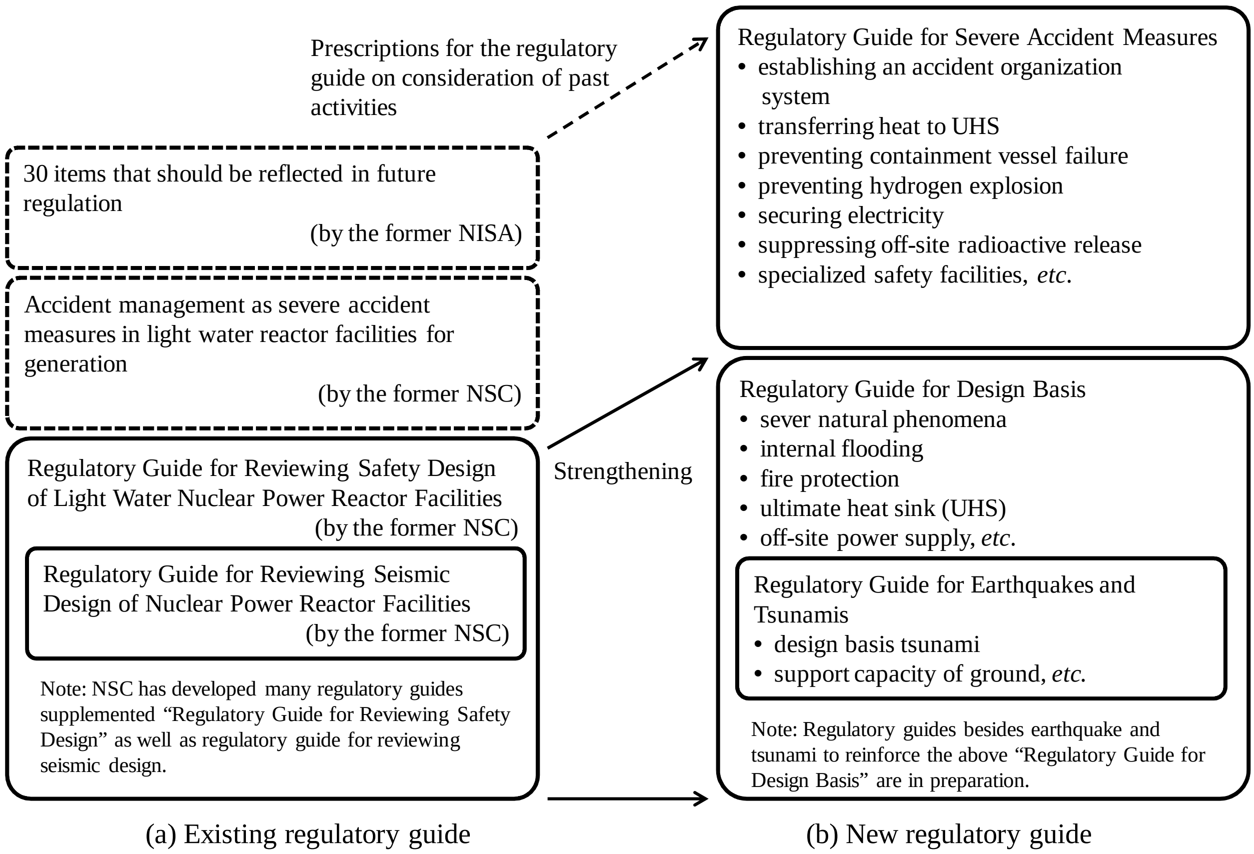

Fig.1 Outline of the new regulatory guide.

these new severe accident measures are prescribed in the latest guide. The major items and comparisons with the existing regulatory guide for earthquakes and tsunamis and the design basis are described in sections 3 and 4, respectively. The major severe accident measures are described in section 5. Lastly, the paper introduces the correspondence of the only currently operating NPPs - Ohi Units 3 and 4 - with the new regulatory guide.

2 Basic policies for developing the new regulatory guide

The NRA announced the following basic policies on the development of the new regulatory guide. The existing regulatory guide are intended to prevent core damage and assumed only a single component failure. In the new regulatory guide, the design basis, including seismic design, is strengthened and severe accident measures for situations beyond the occurrence of core damage have been added.

2.1 Basic policies

(1) Thorough defense in depth
- Prepare plural (multi-layer) protection measures to achieve the safety of NPPs effectively.
- Achieve the safety within only the layer concerned when thinking about the measures for each layer.
- Assume that the measures in the preceding step are broken through within the layer concerned.
- Assume that the measures in the following step do not function.

(2) Improvement of reliability
- Strengthen the fire protection measures.
- Introduce internal flooding measures.
- Exclude the common use of passive components for a significant period of time.

(3) Measures for common cause failure
- Strengthen assumptions and protection measures to effects from common cause failure by natural phenomena.
- Evaluate earthquakes and tsunamis strictly.
- Introduce anti-tsunami measures.
- Make sufficient consideration of diversity and independence of measures.

2.2 Severe accident measures

- Prepare the multi-stage protection measures that are, preventing core damage, maintaining containment function, managing containment vent and controlling radiological material release.
- Adapt the portable components and improve reliability by combination with existing components.
- Strengthen the protection measures of spent fuel pools.
- Improve the leadership of the emergency center, including reliability of communication features.
- Strengthen the instrument system including for the spent fuel pool.
- Prepare the specific safe facilities for intentional airplane crash.

3 Earthquakes and tsunamis

Table 1 shows the constitution of the new regulatory guide for earthquakes and tsunamis. The main design basis elements that have been strengthened are as follows:

(1) Facilities important to safety functions shall be installed on ground that has been confirmed to have no outcrops such as dislocations which may be active in the future. – refer to item 1.1(1) of Table 1

The requirements of the existing safety standard (*i.e.* systems, structures and components (SSCs) should be installed on ground with sufficient support performance) are revised to not having a serious effect on safety function by dislocation *etc.* in the future.

(2) Facilities important to safety functions shall be designed in such a way that they do not lose their safety functions against a design basis tsunami that is extremely rare, but may possibly occur in its service period and have a significant effect on it. - refer to item 1.1(4) of Table 1

The development of the design basis tsunami with the design basis earthquake is prescribed based on the lessons from the Fukushima accident.

(3) Facilities and SSCs which protect Class S facilities (the superlative degree for earthquakes) against tsunami effects and SSCs which have tsunami monitoring functions at the site shall belong to Class S in view of the effect of loss of the functions concerned which may possibly occur due to earthquakes. - refer to item 2.2 of Table 1

This item is prescribed based on the lessons from the Fukushima accident.

(4) Ground on which facilities are installed shall have adequate support capacity against expected seismic forces. - refer to items 5.1 to 5.3 of Table 1

This item is prescribed to confirm broad and local support performance.

(5) The design basis tsunami used for safety design of facilities shall be that which is considered appropriate based on the latest scientific and technological knowledge. - refer to items 6 and 7 of Table 1

The design policy for tsunamis is newly prescribed based on the lessons from the Fukushima accident.

(6) Facilities shall be designed so that their safety functions will not be seriously affected even when faced with the postulated slope failure surrounding them during an earthquake. - refer to item 8 of Table 1

This item is added to protect the facilities from the postulated slope failure.

4 Design basis

Table 2 shows the constitution of the new regulatory guide for design basis. The new design basis is listed in contrast to the previous design basis (*i.e.* Regulatory Guide for Reviewing Safety Design of Light Water Nuclear Power Reactor Facilities). The main design basis elements strengthened this time are as follows:

(1) SSCs important to safety functions shall be so designed that the safety of NPP facilities will not be impaired by other postulated natural phenomena than earthquake, tsunami and concomitant events. SSCs with safety functions of especially high importance shall be of a design that reflects appropriate safety considerations against the severest conditions of anticipated natural phenomena or appropriate combinations of natural forces and design basis accident-induced loads. – refer to item 2(1)2 of Table 2

This item is fundamentally the same as the existing design basis, but tornadoes, influence of the volcanoes, forest fires *etc.* are added as natural phenomena.

(2) SSCs important to functions shall be so designed that the safety of the facilities will not be impaired by postulated internal flooding that may take place inside the NPP. – refer to item 2(4) of Table 2

This is newly prescribed based on the lessons from the Fukushima accident.

(3) Facilities shall be so designed that their safety will not be impaired by fire considering individual protective measures for preventing, detecting and extinguishing fire, and mitigating its effect. – refer to item 2(5) of Table 2

This item is fundamentally the same as the existing design basis, but the NRA proposes a policy to strengthen the fire protection requirement.

(4) SSCs important to safety functions shall be so designed that their sufficiently high reliability will be ensured and maintained to achieve their safety functions even in the case where off-site power is unavailable in addition to the assumption of a single failure. The systems shall be designed with redundancy or diversity, and with independence. – refer to item 2(9) of Table 2

This item is basically the same as the existing design basis, but the NRA proposes a policy to carry out strict evaluations.

(5) The systems for transporting heat to an ultimate heat sink (UHS) shall be designed in consideration of physical protection against design basis tsunamis, flooding, and external man-induced events. – refer to item 3(4)(d)3 of Table 2

This item is newly prescribed based on the lessons from the Fukushima accident.

(6) Off-site power shall be connected to the electric power system with two or more power transmission lines which are connected to two or more independent substations or switchyards. Also, in the case of a multi-unit NPP, it shall be designed so that the loss of any two power transmission lines may not cause the loss of off-site power at the same time. In addition, the emergency on-site power systems shall have sufficient capacity and function even with the assumption of a single power system failure. – refer to item 2(1)2 of Table 2

The independence of the off-site power supply and the required back-up days of AC power supply facilities (emergency diesel generators *etc.*) are strengthened based on the lessons from the Fukushima accident. These requirements are listed in the 30 safety measures by NISA.

5 Severe accident measures

The former NSC recommended that utilities implement effective accident management that reduces the safety risk of the NPP. It pushed for concrete examination of the facilities for containment venting and hydrogen combustion in BWR and PWR, respectively. However, long-term total AC power supply loss by common cause failure due to a severe natural phenomenon (other than earthquake) was not the primary target of examination. In the current regulatory guide, the NRA has established new measures to prevent core damage in case of beyond-design basis accidents (B-DBA) in considering the 30 safety measures. Table 3 shows the constituents of the new regulatory guide for severe accident measures. The main newly-prescribed severe accident measures are as follows:

(1) Appropriate organizational systems shall be established by formulating procedures and implementing drills in advance in order to manage B-DBA rapidly and flexibly. – refer to item 2(2) of Table 3

This item is prescribed in detail as one of the 30 safety measures from NISA.

(2) Equipment and procedures for transferring heat to the UHS shall be prepared that act by restoring or substituting related functions in order to prevent either severe core damage or containment vessel failure even if the design basis function to transfer heat to the UHS is lost. – refer to item 2(7) of Table 3

This item is prescribed in detail as one of the 30 safety measures.

(3) Equipment and procedures *etc.* for reducing the pressure and temperature inside the containment vessel shall be installed in order to prevent containment vessel failure in the event of severe core damage. – refer to item 2(9) of Table 3

This item requires the installation of filtered vent facilities in the containment vessel. This is also listed in the 30 safety measures.

(4) Equipment and procedures for preventing hydrogen explosions in the containment vessel shall be prepared in order to prevent containment vessel failure in the event of severe core damage. – refer to item 2(11) of Table 3
It is required that the containment atmospheres of BWR become inactive and that some types of PWR (*i.e.* ice-condenser type containment) install facilities to control hydrogen concentration.

(5) Equipment and procedures for securing required electricity shall be prepared in order to prevent severe core damage, containment vessel failure, fuel damage in spent fuel storage pools, and fuel damage during reactor shutdown in case of accidents with loss of power. – refer to item 2(15) of Table 3
It is required that the alternate power supply is independent of design basis facilities and that positional dispersion is planned. Portable alternate power supplies and alternate permanent power supply are also required. In addition, the NRA prescribes the capacity of the DC power supply in place. This item is listed in the 30 safety measures.

(6) Facilities and procedures shall be prepared in order to maintain function as a local command center, such as communicating with the relevant parties both inside and outside the power station, and accommodating required personnel, while giving instructions on necessary measures in the event of B-DBA. – refer to item 2(17) of Table 3
This item is prescribed in detail as one of the 30 safety measures.

(7) Equipment and procedures for estimating necessary plant data shall be prepared in order to obtain the necessary plant data in the event of the malfunction of normal and emergency instrumentation devices caused by B-DBA. – refer to item 2(18) of Table 3
This item is prescribed in detail as one of the 30 safety measures by NISA.

(8) Equipment and procedures shall be prepared to suppress off-site radioactive material release in the event of severe core damage and containment failure or fuel damage in spent fuel storage pools. – refer to item 2(21) of Table 3
This item is newly-prescribed.

(9) Procedures shall be prepared for the situation in which the plant has suffered large-scale damage due to a large-scale natural disaster or acts of terrorism such as intentional airplane crashes. Furthermore, organizational systems and necessary equipment enabling these activities in accordance with the procedures shall be prepared. – refer to item 3(1) of Table 3
This item is newly-prescribed.

(10) Specialized safety facilities shall be installed with adequate measures, such as preventing the loss of necessary functions due to the intentional crashing of a large airplane or design basis seismic motion and tsunamis. Equipment shall be designed so as to allow the use over a certain period of time. – refer to item 3(2) of Table 3
This item is newly-prescribed.

(11) Utilities shall postulate B-DBA which may cause severe core damage and prepare appropriate measures to prevent severe core damage and containment vessel failure. – refer to item 4 of Table 3
This item is newly-prescribed.

6 Correspondence of utilities to the new regulatory guide

Immediately after the Fukushima accident, NISA ordered the enforcement (by utilities) of emergency safety measures at NPPs and confirmed the results. Then, NISA started a comprehensive assessment to affect the safety of NPPs sequentially in response to the request of the NSC. However, when the assessment of Ohi Units 3 and 4 - operated by the Kansai Electric Power Company Inc. (KEPCO) - was completed, the government changed the nuclear regulatory system and permitted the start-up of Ohi Units 3 and 4 considering the electricity demand and decided to judge the start-up of other NPPs under the new regulatory system. From these processes, the safety review of Ohi Units 3 and 4 will be started first, and subsequently the safety review of other NPPs will be carried out.

This section introduces the outline of the measures that KEPCO developed at Ohi Units 3 and 4 towards assessment under the new regulatory guide [6 -7]. Some measures have been completed in accordance with the 30 safety measures from NISA after the Fukushima accident.

6.1 Earthquakes and tsunamis

(1) KEPCO carried out a crush zone investigation on the site and confirmed that it had installed its safety-related facilities on confirmed ground where dislocations which might be active in the future did not appear at the surface.

(2) It confirmed that the development of the design basis earthquake was proper, based on the latest knowledge.

(3) It examined earthquakes which could be generated by active faults in the neighboring sea area and confirmed that the development of the design basis tsunami was proper based on the latest knowledge.

(4) It confirmed that the safety-related facilities could maintain safety functions against the design basis earthquake, from the result of earthquake-resistance evaluation.

(5) It confirmed that the safety-related facilities could maintain safety functions because the site height of safety-related facilities was higher than the design basis tsunami height.

6.2 Design basis

(1) KEPCO confirmed that safety-related facilities could not be damaged by natural phenomena (including volcanoes, tornadoes, forest fires *etc.*).

(2) It confirmed that safety-related facilities were designed considering prevention, detection of fire and fire protection measures, and that incombustible cables were in use.

(3) It confirmed that the off-site power supply system was connected to two independent transformer substations in the power grid by 4 lines.

(4) It confirmed that the reactor could be safely cooled down by turbine driven auxiliary feedwater pumps and appropriate water sources during a total AC power supply loss.

(5) It confirmed that it had available diverse communication facilities including satellite phones.

(6) It confirmed that the equipment for the UHS was installed higher than the design basis tsunami height.

(7) It confirmed that the control room was structurally protected from fire and radiation so operators and other staff can stay in it and perform the emergency measures in the event of an accident.

6.3 Severe accident measures

(1) KEPCO developed procedures to have power supply cars and an air-cooled emergency diesel generator installed to secure sufficient electricity for prevention of core damage. In addition, it confirmed that emergency use batteries and normal use batteries could be connected and these batteries could be co-utilized between the units.

(2) It installed portable and permanent alternate water injection facilities. It prepared these with multiple connection mouths to be able to use it for multiple dispersed onsite operations simultaneously.

(3) It upgraded an emergency response center and deployed resources necessary for radiation management for emergency staff and workers, and radiation exposure reduction measures.

(4) It confirmed that the hydrogen concentration in the containment at the time of a severe accident would not cause a hydrogen explosion. For safety improvement, it installed a static catalyst-type hydrogen recombination device.

(5) It prepared spare parts necessary for exchange of safety-related equipment (*i.e.* motors for seawater pumps).

(6) It installed a water cannon and a silt fence to suppress the release of radioactive material to the environment.

(7) It undertook maintenance on the seawater infusion line to containment recirculation units to reduce the pressure and temperature of containment.

(8) It decided to install the containment filtered vent system within five years.

Table 1 Constitution of the new regulatory guide (earthquakes and tsunamis)

Item	Basic requirements	Notes
1. Basic Design Policy for Earthquakes and Tsunamis	1. Since a nuclear power reactor facility must be provided with high safety as a whole, the following basic design policy shall be satisfied. (1) Facilities with important safety functions shall be established on the ground that has been confirmed to have no outcrop of a fault, etc. with the possibility of becoming active in the future. (4) Facilities with important safety functions shall be designed in such a way that they do not lose their safety functions against a tsunami that rarely occurs, but may possibly occur in service period of the facilities and have a significant effect on the facility.	(1)
2. Classification of Importance of Facilities	2. Facilities/SSCs which protect Class S facilities provided in item 1 against tsunami effect and SSCs which have tsunami monitoring functions at the site shall belong to Class S in view of the effect of a loss of the functions concerned that may possibly occur due to an earthquake.	(1)
3. Formulation of Standard Seismic Motion	It is appropriate to formulate the standard seismic motion used for the seismic design of facilities from the seismological and earthquake engineering point of view on geology, geological structure, soil structure, seismicity, etc. of the site and its surrounding area based on the latest scientific and technological knowledge and findings. The standard seismic motion shall be formulated according to the following policies.	(3)
4. Seismic Design Policy	Facilities shall meet the basic policy related to the seismic design by seismic design class as described as follows:	(3)
5. Considerations Regarding Ground Stability	1. Ground on which facilities are established shall have an adequate support capacity against expected seismic forces. 2. The safety functions of equipment and systems belonging to Class S in terms of importance in seismic design classification (hereinafter referred to as Class S equipment and systems) shall not be significantly affected by the tilt and folding of bearing ground (supporting soil) caused by crustal movement due to earthquakes. 3. Facilities having important safety functions shall not be seriously affected and lose their safety function by earthquake-induced abnormal conditions of surrounding ground, abnormal conditions such as uneven subsidence among buildings and structures (uneven settlement), liquefaction, consolidation settlement ,etc.	(2)
6. Formulation of Design Basis Tsunami	Design basis tsunami used for facilities safety design shall be appropriate based on the latest scientific and technological knowledge and taking into account the submarine topography from offshore tsunami source area to site vicinity and seismological viewpoint of geological structure and earthquake activities of offshore. Design basis tsunami shall be determined while taking into account earthquakes and other factors, such as landslides and slope failure, as well as their multiple combinations. Also uncertainty shall be taken into account and numerical analyses shall be carried out before determining the design basis tsunami.	(1)
7. Design Policy against Tsunami	Since reactor facilities need to be highly safe against tsunami, they shall satisfy the following basic design policies so that they will not lose their safety functions even in the face of a design basis tsunami: 1. A site where facilities having important safety functions are located shall prevent the design basis tsunami from directly reaching and intruding into them overland. Moreover, water intrusion into the facility through intake and discharge channel etc. should be prevented. 2. Possibility of water leakage from any channel into water intake/discharge facilities, underground parts, etc. shall be considered. Ranges that may be flooded due to water leakage shall be limited to prevent such leakage from affecting the safety function of facilities. 3. Measures other than flood protection measures shall be taken to isolate important safety functions from tsunami effects. 4. Effect of lowered water intake capability due to water level fluctuation on Facility safety functions shall be prevented. 5. With regard to tsunami preventing facilities and equipment, their tsunami protection function and inundation prevention function shall be maintained against design basis input tsunami. And with regard to tsunami monitoring SSCs, their tsunami monitoring function shall be maintained against input tsunami. 6. Site upheaval and subsidence due to earthquakes, impacts of ground motions generated by main shocks and aftershocks, post-earthquake tsunami attack, repetitive tsunami attacks and tsunami-caused secondary effects shall be taken into account.	(1)
8. Design Considerations regarding the Stability of Surrounding Slope	A facility shall be designed so that its safety functions will not be seriously affected even when faced with the postulated slope failure surrounding it during earthquake.	(2)

(1) This requirement is added to the new regulatory guide based on the lessons of the Fukushima accident.

(2) This requirement is added to the new regulatory guide to enhance the safety of the facilities.

(3) This requirement follows the way of thinking of the existing regulatory guide.

Table 2 Constitution of the new regulatory guide (design basis)

Item and basic requirements	Notes
1. General Rules	
(1) Definitions of Terms	(3)
(2) Applied Codes and Standards	(3)
2. General Technical Requirements for Nuclear Reactor Facilities	
(1) Design Considerations against Natural Phenomena	(1)
(Natural phenomena other than earthquakes)	
2. SSCs with safety functions shall be so designed that the safety of the nuclear reactor facilities will not be impaired by other postulated natural phenomena than earthquake, tsunami and concomitant events. SSCs with safety functions of especially high importance shall be of the design that reflects appropriate safety considerations against the severest conditions of anticipated natural phenomena or appropriate combinations of natural forces and design basis accidents-induced loads.	
(2) Design Considerations against External Man-Induced Events	(3)
(3) Design Considerations against Internal Missiles	(3)
(4) Design Considerations for Internal Flooding	(1)
SSCs with safety functions shall be so designed that the safety of the nuclear reactor facilities will not be impaired by postulated internal flooding that may take place within the nuclear reactor facilities. Also, leakage from radiation controlled area shall be prevented by design in case of postulated internal flooding with radioactive materials.	
(5) Design Considerations against Fire	(2)
The nuclear reactor facilities shall be so designed that their safety will not be impaired by fire considering individual protective measure for preventing, detecting and extinguishing fire, and mitigating its effect. Also, those protective measures shall be so designed as not to impair the safety functions of SSCs with safety functions as a result of their failure or malfunction.	
(6) Design Considerations against Environmental Conditions	(3)
(7) Design Considerations for Sharing	(2)
SSCs with safety functions of especially high importance shall generally not be shared or interconnected between multiple units unless it contributes to enhance safety.	
(8) Design Considerations against Operators' Actions	(2)
The nuclear reactor facilities shall be designed taking appropriate preventive measures against operator error. SSCs with safety functions comprising the nuclear reactor facilities shall also be designed for operators to operate easily under the environmental conditions under which operation is required.	
(9) Design Considerations for Reliability	(3)
(10) Design Considerations for feasibility of Test and Inspection	(3)
(11) Design Considerations for Communication Systems	(3)
(12) Design Considerations for Escape Routes	(1)
2. The nuclear reactor facilities shall be provided with lightning and dedicated power supplies that enable on-the-spot work to respond to an accident - separate from the evacuation lightning.	
3. Individual Systems of Nuclear Reactor Facility	
(1) Reactor Core and Associated Features	(3)
(2) Reactivity Control System and Reactor Shutdown System	(3)
(3) Reactor Coolant Pressure Boundary	(3)
(4) Reactor Cooling System	
(d) Systems for Transporting Heat to Ultimate Heat Sink	(1)
3. The systems for transporting heat to an ultimate heat sink shall be designed in consideration of physical protections against design basis tsunami, flooding, and external man-induced events.	
(e) Steam Turbine and Associated Equipment	(4)
(5) Reactor Containment Facility	(3)
(6) Instrumentation and Control Systems	(1)
(a) Instrumentation and Control Systems	
1. The instrumentation and control systems shall be designed to satisfy the following requirements during normal operations and anticipated operational occurrences.	
(1) The parameters necessary to maintain the integrity of the reactor core, reactor coolant pressure boundary, reactor containment boundary, fuel storage facility and associated systems shall be controlled and maintained within presumed range.	
(b)Safety Protection Systems	
6. The safety protection system shall be designed to take into account cyber security such as the prevention of intrusion from an external network.	
(c) Control Room and Others (excluding habitability)	
2. The control room shall be designed so that it can grasp the situation outside the nuclear reactor facility.	
(7) Electrical Systems	(1)
(a) Basic Requirements related to the Safety Design of Electrical Systems for the Nuclear Reactor Facilities	
1. The electrical systems shall be designed so that the SSCs with safety functions of especially high importance can be supplied with electricity by either of off-site power (transmission grid) and emergency on-site power when they need electricity to fulfill their safety functions and be designed so that the reliability of electricity supply can be ensured and maintained at sufficient levels. In addition, the electrical systems shall be designed so that the abnormal event can be detected and prevented from its expansion and spread, thereby no loss of required power is ensured due to the failure of the related electrical system equipment, such as a main generator,	

external power supply, emergency auxiliary power supply, or disturbance of the off-site power (transmission grid) and the like.

2. The off-site power system shall be connected to the electric power system with two or more power transmission lines which are connected to two or more independent substations or switchyards and which at least one line out of these lines is physically separated from other lines. Also, in the case of multiple reactor nuclear power stations, it shall be designed so that the loss of any two lines of power transmission lines may not cause the loss of off-site power at a same time in these nuclear reactor facilities.

3. The emergency on-site power systems shall have enough capacity and function sure to accomplish the following even with an assumption of a single power systems failure.

(3) Not depending on sharing the emergency on-site power systems among two or more nuclear reactor facilities.

4. The emergency on-site power systems shall be designed so that they can supply required power during a loss of off-site power for a certain period of time.

(b) Basic Requirements related to Electric Facilities for Nuclear Power Generation

1. The switchyard, large transformers and main generators of the electric facilities for nuclear power generation shall be designed so that they may not cause damages to other equipment, taking the isolation of electric circuits, prevention of disconnection, grounding, ground fault protection, over current protection, heat resistance and mechanical impact caused by short-circuit current into considerations.

2. The compressor systems and gas insulated circuit breakers shall be designed so as to be able not only to monitor and control the working pressure, but also to adequately withstand it, and to be corrosion resistant.

3. The rotating part of the main generator shall be designed to have sufficient mechanical strength. Furthermore, for the main generators of the hydrogen-cooling type, they shall be designed so that the leak of hydrogen and mixing in air can be prevented and that the leak of hydrogen can be detected if it occurs, alarms set off, the leaks are sealed and the leakage is discharged to the outdoors.

4. The lightning arrester and the like shall be installed with the electric facilities so that their electric circuits may not be damaged by lightning strike.

(8) Design Considerations against Station Black-out (3)

(9) Radioactive Waste Management Systems (3)

(10) Fuel Handling Systems (1)

5. The storage and handling systems for fresh and spent fuels shall be designed so that the water level and water temperature of the spent fuel storage facility are maintained except where using dry storage casks, the radiation level in the fuel handling area and other abnormalities can be detected and that such a situation can be properly communicated to the site personnel or corrective measures can be automatically taken. Also, they shall be designed so that the situation of any events can be monitored through more than one parameter even in the case of loss of off-site power.

(11) Radiation Management (1)

(c) Monitoring Equipment

The nuclear reactor facilities shall be designed to enable proper radiation monitoring and surveillance against the release of radioactive materials and measurement of the dose rate can be performed so that it allows necessary information to be displayed in the control room or in other appropriate places during normal operations, anticipated operational occurrences and design basis accidents.

(12) Others (Auxiliary Boiler) (1)

(a) Basic Requirements for Auxiliary Boilers (5)

4. Safety Evaluation

(1) Safety Evaluation (2)

1. In order to verify that the basic policy of safety design of nuclear reactor facilities conforms to validity, the safety evaluation against anticipated operational occurrences and design basis accidents must be conducted.

2. It shall be verified that the safety evaluation referred to in the preceding paragraph pertaining to anticipated operational occurrences satisfy the pertinent criteria specified below.

(1) The minimum critical heat flux ratio or the minimum critical power ratio shall be larger than the acceptable limit.

(2) Fuel cladding shall not be mechanically damaged.

(3) Fuel enthalpy shall not exceed the acceptable limit.

(4) Pressure on the reactor coolant pressure boundary shall not exceed 110% of the maximum allowable working pressure.

3. It shall be verified that the safety evaluation referred to in paragraph 1 pertaining to design basis accidents satisfy the pertinent criteria specified below.

(1) The core shall be without significant damage, and adequate coolable configuration of the core shall be maintained.

(2) Fuel enthalpy shall not exceed the specified limit.

(3) Pressure on the reactor coolant pressure boundary shall not exceed 120% of the maximum allowable working pressure.

(4) Pressure on the reactor containment boundary shall not exceed the maximum allowable working pressure.

(5) The accident shall not give significant radiological risk to the off-site public.

(1) This requirement is added to the new regulatory guide or revised from the existing regulatory guide based on the lessons of the Fukushima accident.

(2) This requirement is added to the new regulatory guide or revised from the existing regulatory guide to enhance the safety of the features.

(3) This requirement follows the way of thinking of the existing regulatory guide.

(4) Steam turbine and associated components which comes to be regulated by the Reactor Regulation Act as a result of its integration with the Electricity Business Act.

(5) Auxiliary boiler to be regulated by the Reactor Regulation Law as a result of its unification with the Electricity Utilities Industry Law.

Table 3 Constitution of the new regulatory guide (severe accident measures)

Item and basic requirements	Notes
1. Definitions of Terms (Severe Accident Measures-related)	
2. Requirements on the Severe Accident Measures (Major systems for each measure)	
(1) Common Requirements (a) Requirements on the Severe Accident Measures Equipment Capacity, Operability, Diversity, Detrimental impact prevention, Easy Changeover, Reliable connections, Seismic and Tsunami Resistance etc. (connecting piping included), Storage places, On-site working conditions, Securing access routes, and Prohibition of shared use (b) Requirements for recovery work Securing spare parts, Storage place, and Securing access routes (c) Miscellaneous Requirements Support	(1)
(2) Preparation of procedures, implementation of drills and development of organizational system Appropriate organizational system shall be established by the formulation of the procedures and implementation of drills in advance in order to manage B-DBA rapidly and flexibly.	(2)
(3) Measures for reactor shutdown Prepare equipment and procedures for maintaining reactor sub-criticality in order to prevent severe core damage in the event of an anticipated transient without scram (ATWS) or indications of ATWS, while maintaining the integrity of the reactor coolant pressure boundaries and the containment vessel.	(2)
(4) Measures for cooling reactor at high pressure Establish equipment and procedures for cooling the reactor by recovering the relevant system or using alternative system in order to prevent severe core damage in the event that reactor cooling function is lost when the pressure of reactor coolant pressure boundaries is high.	(2)
(5) Measures for depressurization of reactor coolant pressure boundaries Prepare equipment and procedures, etc., for depressurizing reactor coolant pressure boundaries by recovering the relevant system or by using alternative system, in order to prevent severe core damage and containment vessel failure in the event that depressurization function is lost when the pressure of reactor coolant pressure boundaries is high.	(2)
(6) Measures for cooling reactor at low pressure Prepare equipment and procedures etc. for cooling the reactor by recovering and substituting the related function in order to prevent severe core damage and prevent containment vessel failure in the event that reactor cooling function is lost when the pressure of reactor coolant pressure boundaries is low.	(2)
(7) Measures for securing an ultimate heat sink for the Severe Accident Measures in case of accident Prepare equipment and procedures for transferring heat to ultimate heat sink by restoring or substituting related functions in order to prevent either severe core damage or containment vessel failure at the stage prior to core damage in the event that the function to transfer the heat to the ultimate heat sink (UHS) is lost.	(2)
(8) Measures for cooling, depressurization and radioactive material reduction in the atmosphere of the containment vessel 1 Prepare equipment and procedures etc. to reduce the pressure and temperature in the atmosphere of the containment vessel in order to prevent the severe core damage in case of loss of cooling function of the atmosphere of the containment vessel. 2 Prepare equipment and procedures etc. to reduce the pressure, temperature and concentration of the radioactive materials in the atmosphere of containment vessel to prevent containment failure in case of severe core damage.	(2)
(9) Measures for preventing the containment vessel failure due to overpressurization Equipment and procedures etc. for reducing the atmospheric pressure and temperature inside the containment vessel shall be installed in order to prevent containment vessel failure in the event of severe core damage.	(1)
(10) Measures for cooling molten core fallen to the bottom of the containment vessel Prepare equipment and procedures for cooling the molten core fallen to the bottom of the containment vessel in order to prevent containment vessel failure in the event of severe core damage.	(1)
(11) Measures against hydrogen explosions inside the containment vessel Prepare equipment and procedures for preventing hydrogen explosions in the containment vessel in order to prevent containment vessel failure in the event of severe core damage.	(2)
(12) Measures against hydrogen explosions inside the reactor building, etc. Prepare equipment and procedures etc. for preventing damage to the reactor building and containment vessel annulus by the accumulation and explosion of the hydrogen in the event of severe core damage.	(2)
(13) Measures for cooling, shielding and maintaining the sub-criticality of spent fuel storage pools 1 Prepare equipment and procedures for cooling of the fuels in the spent fuel pool, shielding and preventing criticality in the event of loss of spent fuel storage pool cooling function, or cooling water injection function or leakage of a small amount of pool water. 2 Prepare equipment and procedures for mitigating fuel damage and preventing criticality in the event that spent fuel storage pool water level cannot be maintained due to the leakage of a large amount of water.	(2)
(14) Measures for securing make-up water and water sources Prepare equipment and procedures that provide the water to the design basis equipment and Severe Accident Measures Equipment by securing the water sources for design basis equipment as well as sufficient water from those sources necessary to manage severe core damage etc.	(2)
(15) Measures for securing power sources Prepare equipment and procedures for securing electricity required to prevent severe core damage, prevent containment vessel failure, prevent fuel damage in spent fuel storage pool, and prevent fuel damage during reactor	(2)

shutdown in case of the accident with loss of power.	
(16) Control room 1 Prepare equipment and procedures that enable operators to remain in the control room as long as possible and respond to an event in the event of severe core damage. 2 Prepare the backup control room in case of loosing availability of control room.	(1) & (2)
(17) Emergency response center Install facility and procedures to maintain function as a local command center, such as communicating with the relevant parties both inside and outside the power station, and accommodating required personnel, while giving necessary measures instructions in the event of beyond design basis accidents.	(2)
(18) Instrumentation facilities Prepare equipment and procedures for estimating necessary plant data in the event that difficulties arise to get the necessary plant data due to the malfunction of some normal and emergency instrumentation devices caused by B-DBA.	(2)
(19) Radiation monitoring facilities 1 Prepare equipment and procedures for monitoring, measuring and recording radioactive material released from nuclear facilities and radiation conditions both on shore and at sea in the event of severe core damage. 2 Prepare equipment and procedures for measuring and recording wind direction and wind speed, etc.	(2)
(20) Communications equipment Prepare equipment and procedures for communicating with necessary locations both within and outside the nuclear power plant in the event of beyond design basis accidents.	(2)
(21) Measures for suppression of off-site radioactive material release Prepare equipment and procedures for suppressing off-site radioactive material release in the event of severe core damage and containment failure or fuel damage in spent fuel storage pool.	(2)
3. Accident Management for External Events beyond Design Basis	
(1) Accident management with mobile equipment, etc. Procedures shall be prepared for the following items under the situation that the plant has suffered large-scale damage due to a large-scale natural disaster or acts of terrorism such as intentional airplane crash. Furthermore, organizational systems and necessary equipment enabling these activities in accordance with the procedures shall be prepared. a. Activities to extinguish a large-scale fire b. Measures to mitigate fuel damage c. Measures to mitigate containment vessel failure. d. Measures to minimize the release of radioactive material e. Measures to maintain necessary water levels and measures to mitigate fuel damage in spent fuel storage pools	(2)
(2) Specialized Safety Facility (Requirements for Specified Safety Facility) 1 Specialized Safety Facility shall be installed in accordance with the following. a. Specialized Safety Facility shall be equipped with adequate measures for preventing the loss of necessary function due to the intentional crashing of a large airplane into the reactor building. b. Specialized Safety Facility shall be equipped with adequate measures for preventing the loss of necessary function due to design basis seismic motion and tsunamis. c. Specialized Safety Facility shall be installed with equipment required to prevent containment vessel failure. d. Equipment shall be designed so as to allow the use over a certain period of time. (Establish organizational systems to maintain the function of Specialized Safety Facility) 2 Organization to maintain the function of Specialized Safety Facility shall be established.	(1)
4. Evaluation of the Effectiveness of Severe Accident Measures	
(1) Evaluation of the Effectiveness of preventive measures against severe core damage and containment vessel failure (Evaluation of the Effectiveness of preventive measures against severe core damage) 1 Licensees must postulate B-DBA which may cause severe core damage and prepare appropriate measures to prevent severe core damage. (Evaluation of the Effectiveness of preventive measures against containment vessel failure) 2 Licensees must postulate the containment vessel failure mode that may occur in conjunction with severe core damage and prepare appropriate measures to prevent containment vessel failure.	(1)
(2) Evaluation of the Effectiveness of preventive measures against severe fuel damage in spent fuel storage pools 1 Licensees must prepare appropriate preventive measures against fuel damage by postulating an accident that may cause severe damage to the fuel stored in spent fuel storage pools	(1)
(3) Evaluation of the Effectiveness of preventive measures against fuel damage in a reactor during shutdown 1 Licensees must prepare appropriate preventive measures against fuel damage in reactor during shutdown assuming the possibility of an accident that that may cause severe damage to the fuel in reactor during shutdown	(1)

(1) This requirement is added to the new regulatory guide.
(2) This requirement follows the way of thinking of the existing regulation.

Closing remarks

The new regulatory guide for NPPs is revised or newly-prescribed based on the lessons from the Fukushima accident and with referral to international standards. In addition, this regulatory guide shall be applied to the existing NPPs (*i.e.* back fit system) in accordance with the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors amended on June 27, 2012. The NRA has a policy to perform the annual inspection and the periodical safe review of NPPs, especially in case of more than 40 years extension of operation period, strictly in accordance with this regulatory guide and authorize the operation only for NPPs whose safety has been confirmed. Although it is clear that the guide improves the safety of NPPs, its effectiveness and adequacy depend on the continuous and cooperative efforts by both regulatory organizations and utilities in future. Hereafter, it will be confirmed in the discussion of the safety review to judge the appropriateness of start-up of NPPs.

Nomenclature

DBA	Design Basis Accident
KEPCO	Kansai Electric Power Company Inc.
NISA	Nuclear and Industrial Safety Agency
NRA	Nuclear Regulation Authority
NSC	Nuclear Safety Commission
SSCs	Systems, Structures and Components
UHS	Ultimate Heat Sink

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[3] Nuclear Regulation Authority: NRA Library, Regulatory guide, Outline of New Regulatory Requirements (Severe Accident Measures).
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[6] Kansai Electric Power Company Inc.: Confirmation result of the compatibility to new regulatory guide on Ohi Units 3 and 4, April 18, 2013 (Japanese).
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