(Provisional Translation)

April 3, 2013

Outline of New Regulatory Requirements For Light Water Nuclear Power Plants (Earthquakes and Tsunamis)

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(Notice)

This document is based on the discussions at the review team meetings on "Investigation of New Safety Design Standard Related to Earthquakes and Tsunamis for Light Water Nuclear Power Reactor Facilities" and public comment result conducted during Feb.7-28 2013.

For standardization, the definition of terms and the contents and configuration of essential features will be summarized on the basis of examples in legislation.

1. Basic Design Policy for Earthquakes and Tsunamis

[Basic requirements] <Standard for Establishment License>

1 Since a nuclear power reactor facility(hereafter called "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.

(2) Facilities with important safety functions shall be designed in such a way that it does not lose these important functions against a seismic force caused by the earthquake ground motion (hereafter called "standard seismic motion") that rarely occurs, but may possibly occur in service period of the facilities and have a significant effect on the facility. In addition, the facility shall be designed in such a way that it can fully sustain a seismic force assumed to be appropriate in accordance with importance in view of the effect of radiation on the environment following a loss of safety functions that may possibly occur due to an earthquake.

(3) Facilities shall be established on the ground with sufficient support capacity against the seismic force provided above.

(4) Facilities with important safety functions shall be designed in such a way that it does not lose its safety functions against a tsunami (hereafter called "design basis tsunami") that rarely occurs, but may possibly occur in service period of the facilities and have a significant effect on the facility.

2. With regards to survey for formulating the standard seismic motion and design basis tsunami, etc., survey method shall be selected in accordance with the purpose and the reliability and precision of the survey results shall be ensured by taking into account the application conditions and precision of the survey method.

[Detailed note on requirements] <Internal Rules of the NRA>

(1) A "fault, etc. with the possibility of becoming active in the future" includes a landslide surface that cuts the bearing basement in addition to an active fault taken into account as the hypocenter and a fault that is accompanied by the activity of the fault concerned resulting in a permanent displacement.

(2) “fault, etc. with the possibility of becoming active in the future” means fault of which activities later than the Late Pleistocene (later than 120-130,000 years ago) cannot be denied. To judge this, in case activities later than the Late Pleistocene is not clear according to , for instance, lack of plural or continuous strata of Late Pleistocene, its activities further to be investigated for the Middle Pleistocene (later than 400,000 years ago) through the integrated consideration of geography, geology, geological structure and stress field etc. Note that if confirmation is difficult at installation area where activity is assessed, it should be judged to the conservative side by the behavior of fault etc. confirmed at the extended part of the fault concerned.

(3) The description of “in particular” in No. 1 of Paragraph 1 is provided because if a facility with important safety functions is established in a place with the outcrop of a fault, etc. with the possibility of future activity, the activities of such a fault, etc. in the future may have a significant effect on the safety functions.

(Reference)

With regards to the existence of a “residual risks” related to formulating the standard seismic motion and design basis tsunami

It cannot be denied that an earthquake motion occurs with the strength exceeding that of the standard seismic motion in view of seismology. In addition, it cannot be denied that a tsunami exceeding the design basis tsunami will possibly attack facilities. In formulating the standard seismic motion or design basis tsunami, these matters mean the existence of a “residual risks” (a risk that causes a significant damage event to occur in facilities due to the effect exceeding the standard seismic motion or design basis tsunami that has been formulated on them, that an event that diffuses a large amount of radioactive materials from facilities to occur or at these events result in general public to suffer from radiation exposure). Thus, when a facility is designed, the possibility of the occurrence of an event exceeding the formulated standard seismic motion or design basis tsunami should properly taken into account and the existence of this “residual risks” shall fully be recognized including the stage of the basic design and its subsequent stages to make effort to minimize the risk as far as this approach is feasible.

<The following are major references.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)

2. Classification of Importance of Facilities

[Basic requirements] <Standard for Establishment License>

1. Since a facility must be provided with high safety as a whole, all facilities with important safety function shall belong to Class S in view of preventing a loss of safety functions that may possibly occur by an earthquake followed by the effect of radiation on the environment. Those with less effect than that of Class S can be assigned to Class B. Those other than them and with safety equal to that of general industrial facilities and public facilities can be assigned to Class C.

2. Facilities/SSCs which protect Class S facilities provided in item 1 against tsunami effect (hereafter "tsunami protecting facilities/SSCs"), and SSCs which has tsunami monitoring function at the site(hereafter "tsunami monitoring SSCs") 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.

[Detailed note on requirements] <Internal Rules of the NRA>

The concept of the functional classification of each class and facilities by class is as follows:

(1) The following are based on Paragraph 1.

① Class S

All facilities having important safety function shall be classified as Class S.

"facilities having important safety function" mean that have function to shut down and cool down the reactor, that contain itself radioactive material, that related directly to class S facilities and its loss of function could cause diffusion of radioactive material to outside, that have function to mitigate the influence of accident caused by loss of function of above facilities and to decrease the influence of radiation to environment, and that are necessary and have large effect for supporting above important functions. At least, following facilities should be classified as Class S.

・Equipment and piping systems composing the reactor coolant pressure boundary
・Facility to store spent fuel
・Facility to rapidly add negative reactivity for emergency shut-down of the reactor and facility to maintain the shut-down situation of the reactor.
・Facility to remove decay heat from the core after reactor shut-down

・Facility to remove decay heat from the core after a reactor coolant boundary rupture accident

・Facility to directly prevent the radiation of radioactive materials that become a pressure barrier at a reactor coolant pressure boundary accident

・Facility other than above to suppress the external radiation of radioactive materials at an accident accompanied by their release

② Class B

Facilities of which failure resulting in a small effect compared with Class S could be classified as Class B. For example, the following can be listed.

・A facility connected directly to the reactor coolant pressure boundary and contains or be able to contain the primary coolant

・A facility that contains radioactive waste. However, those facilities are excluded that have a small containing amount or of which effects of radiation on general public due to their damage are sufficiently small due to their storage method compared with an annual dose limit outside the surrounding monitoring area

・A facility associated with radioactive materials except radioactive waste and that may have the possibility of giving excessive radiation exposure to general public and personnel due to its damage

・A facility to cool down spent fuel

・A facility that suppresses the external release of radioactive materials and that does not belong to Class S

(2) Those provided by Paragraph 2 should be as follows. If these facilities lose their functions due to an earthquake, tsunamis may possibly invade while this situation continues and have effect on their important safety functions. For this reason, the importance of their seismic design shall belong to Class S.

① Facilities with tsunami protection functions: Tsunami protection facilities, SSCs with inundation protection functions: Tsunami protection SSCs

② SSCs with tsunami monitoring functions in the site: Tsunami monitoring SSCs(those required to watch tsunami invasion into the site repeatedly, basically based on official tsunami alert and also keep function in case tsunami alert is not available and firmly to ensure the functions of the facility in ① as mentioned above, etc.)

<The following are major references.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)

- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)

3.Formulation of Standard Seismic Motion

[Basic requirements] <Standard for Establishment License>

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.

(1) The standard seismic motion shall be formulated as the earthquake ground motion in the horizontal and vertical directions on the free surface of the base stratum in the site as to the "earthquake ground motion formulated with a hypocenter specified for each site and formulated " in the following paragraph and the "seismic motion formulated without a hypocenter" specified in Paragraph 3, respectively.

(2) The "earthquake ground motion formulated with a hypocenter specified for each site" shall be formulated by selecting multiple earthquakes that are predicted to have a significant effect on the site (hereafter called "earthquakes for investigation") as to inland crustal earthquakes, interplate earthquakes and oceanic intraplate earthquakes and implementing the evaluation of ground motions for each selected earthquake for investigation by the method based on response spectra and the method using the fault model, with uncertainties taken into account and propagation properties up to the free surface of the base stratum reflected.

(3) The "earthquake ground motion formulated without a hypocenter specified" shall be formulated by collecting observation records in the vicinity of a hypocenter that were obtained as to inland crustal earthquakes difficult to associate a seismic source with an active fault and setting up a response spectrum in accordance with the soil properties of the site with various uncertainties taken into account.

[Detailed note on requirements] <Internal Rules of the NRA>

(1) With regards to the character of the standard seismic motion.

The standard seismic motion is the one that is a prerequisite of the seismic design to ensure the seismic safety of a facility. When it is formulated, its adequacy shall be fully confirmed by checking the latest knowledge and findings at the time of individual application.

(2) The interpretation of terms used when the standard seismic motion is formulated is as follows:

① The "free surface of the base stratum" refers to a free surface virtually set up assuming that neither surface layer nor structure exists on the base stratum in order to formulate the standard seismic motion and that is the surface of a bed rock postulated with a almost horizontal considerable extent and without remarkable elevation differences. The "base stratum" referred to here is a hard ground with a shear wave velocity of almost Vs = 700 m/s or more without any remarkable weathering.

② An "inland crustal earthquake" refers to the one that occurs in the seismogenic layer of the upper crust in the continental plate and that includes those occurring slightly offshore from the seashore.

③ An "interplate earthquake" refers to the one that occurs on the boundary between two adjacent plates.

④ An "oceanic intraplate earthquake" refers to the one that occurs inside the subducting ocean plate and it can be divided into two types: the one is the "subducting oceanic intraplate earthquake" that occurs near or slightly seaward of the trench and the other is the "subducted oceanic intraplate earthquake (intraslab earthquake)" that occurs on the landward side of the trench.

(3) An "earthquake ground motion" that is formulated with a hypocenter specified for each site" shall be formulated in accordance with the following policies.

① With regards to an inland crustal earthquake, an interplate earthquake and an ocean intraplate earthquake, the nature of the active fault and the situation of the occurrence of an earthquake shall carefully be examined and existing research results and so on shall comprehensively be studied in relation to the distribution of middle, small and micro types of earthquakes, stress fields and mechanisms (including plate geometry, movement, and interactions.) to select multiple earthquakes (earthquakes for investigation).

② With regards to inland crustal earthquakes, the following shall be taken into account.

i) When an active fault taken into account for seismic design is assessed, the properties of existing literature investigations, geomorphological surveys, geological surveys, geophysical survey, etc. shall effectively be utilized and proper combinations of these surveys shall be implemented, Then, their results shall comprehensively be assessed to clarify the location, geometry and activity of the active fault.

ii) When the fault geometry and parameters of source characterization are estimated, an isolated and short active fault shall be carefully handled, and simultaneous rupture among multiple active faults shall be taken into account.

③ With regards to an interplate earthquake and an oceanic intraplate earthquake, their source areas shall be estimated in light of the large-scale earthquakes that occurred both in Japan and the world as well as the similarity of their seismogenic mechanisms and tectonics backgrounds.

④ An earthquake ground motion shall be evaluated for each earthquake for investigation based on the response spectrum method shown in i) as below and by the method using the fault model in ii) and then formulated.

Ground motion evaluation should be conducted considering fully on earthquake types, characteristics of seismic wave propagation path (including site effect) etc, based on seismic ground motion observation records at the site.

i) The evaluation of an earthquake ground motion based on the response spectrum method

Response spectra shall be evaluated for each earthquake for investigation by using a proper method and the design basis response spectrum shall be estimated based on these response spectra, while the earthquake ground motion shall be evaluated by properly taking into account its properties such as its duration, time history of the amplitude envelope, etc. based on the scale of an earthquake, hypocentral distance, etc.

ii) Evaluation of the seismic hazard based on the method using the fault model

The ground motions shall be evaluated with determination of the parameters of source characterization by using an appropriate method for each earthquake for investigation.

⑤ With regards to various uncertainties (the length of a causative fault, the depth to the top and bottom of the seismogenic layer, the dip of a fault, the location and size of an asperity, the stress drop, the rupture starting point, etc. and uncertainties due to a difference in interpretation) accompanying the process of formulation of the standard seismic motion, dominant parameters shall be analyzed that can be considered to have a significant effect on the evaluation of the seismic hazard and they shall be taken into account by using an appropriate method such as combination of uncertainties.

⑥ If a hypocenter is extremely close to the site among earthquakes for investigation that were selected in relation to earthquakes in inland crusts, the entire fault accompanied by a dislocation on the surface shall be taken into account. Then, it shall be to investigate in detail the adequacy of a fault postulated as the hypocenter, locational relationship with the site and the facilities established in it, and the adequacy of the determination of source characterization parameters. While attention shall be paid to the applicability of the evaluation method based on the results of these reviews, the effect of various uncertainties on the evaluation of ground motions in ⑤ as above shall be evaluated in further detail and the standard seismic motion shall be formulated with a sufficient margin even based on the latest knowledge and findings related to the features of the earthquake ground motion extremely close to the hypocenter.

⑦ The investigation and evaluation carried out when earthquakes for investigation are selected and the standard seismic motion is formulated shall be based on the latest scientific and technological knowledge and findings. With regards to existing materials, etc., their sufficiency and precision shall be fully taken into account and referred to. If the results are obtained that are different from existing evaluations, their bases shall be clarified.

⑧ If there is a facility with earthquake responses dominant in relatively long periods such as the use of the seismic isolation structure for the structure of the facility, attention shall be paid to its frequency characteristics to carry out the evaluation of ground motions and the standard seismic motion shall be formulated differently from that of other facilities.

(4) The "earthquake ground motion formulated without the hypocenter specified" shall be formulated according to the following policies.

① When the "earthquake ground motion formulated without the hypocenter specified" is formulated, the propagation characteristics of a seismic wave up to the free surface of the basement stratum shall be reflected in the determination of a response spectrum when needed. The characteristics of the earthquake ground motion such as the duration of the earthquake ground motion, time history of the amplitude envelop, etc. shall properly be taken into account for the determined response spectrum.

② The adequacy of the standard seismic motion formulated as the "earthquake ground motion formulated without the hypocenter specified" shall individually be confirmed against the latest knowledge and findings at the time of application. At this moment, with regards to the earthquake ground motion close to the hypocenter due to the causative fault without clear trace on the surface, the evaluation shall be referenced such as the probabilistic evaluation with various certainties taken into account.

(5) For the evaluation of ground motions based on the "earthquake ground motion formulated with the hypocenter specified for each site" and "earthquake ground motion formulated without the hypocenter specified", attention shall be paid to characteristic data required for an applicable evaluation method and the following items shall be taken into account related to the propagation characteristics of seismic waves.

① In order to investigate the effect of the underground structure (deep and shallow ground structure) in and around the site on the propagation effects of seismic waves, the geological structure of such as the tilt of the layer, the fault and the fold structure shall be evaluated. In addition, the location and shape of a seismic bed-rock, the heterogeneity of a rock formation, and the underground structure such as the seismic velocity structure, and the damping characteristics of a soil shall be evaluated. Except the case where the underground structure is recognized to be made as stratification and homogeneous in the evaluation process, the three-dimensional underground structure shall be investigated.

② Regarding with the investigation of the site and around required to implement the evaluation in ①, it shall be implemented to investigate the regional characteristics and existing literatures, to collect and analyze existing data, to analyze the observation records of earthquakes, to carry out geological, boring, and two-dimensional or three-dimensional geophysical surveys, etc. by combining them properly with appropriate procedures.

(6) Regarding with the "earthquake ground motion that is formulated with the hypocenter specified for each site" and the "earthquake ground motion that is formulated without the hypocenter specified", their corresponding probabilities of exceedance should be referred and it shall be grasped that their response spectrum corresponds to what level of exceedance probability.

(Reference)

The meaning of “to be referred” in detailed note on requirements(6) is intended to recognize the possibility of the occurrence of an event exceeding the earthquake ground motion that was formulated as described in (Reference) of detailed note on requirements of “1. Basic Policy Regarding Earthquake and Tsunami”. It also means to pay attention properly to “residual risk” for the design of facilities and to continue make efforts to decrease it including the stages after the basic design stage.

<The following are major references.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Preliminary version Reports on “Long Term Evaluation Method of Active Faults” 11/25/2010, Long Term Evaluation Subcommittee, Earthquake Investigation Committee, Earthquake Investigation and Research Promotion Office)

4. Seismic Design Policy

[Basic requirements] < Standard for Establishment License >

Facilities shall meet the basic policy related to the seismic design by seismic design class as described as follows:

(1) Each facility in Class S provided in paragraph 2 “Classification of importance of facilities” item 1 shall keep its safety functions for a seismic force due to the standard seismic motion. In addition, it shall endure, staying in almost elastic region, a larger seismic force either due to the elastic design earthquake ground motion or static seismic force.

Facilities and SSCs in Class S provided in paragraph 2 “Classification of importance of facilities” item 2 and buildings and structures in which tsunami protection facilities are installed shall keep their functions required for each(tsunami protection, inundation protection and tsunami monitoring) against a seismic force due to the standard seismic motion.

(2) Each facility in Class B shall sustain a static seismic force staying in almost elastic region. In addition, for those facilities that may cause resonance to occur, its effect shall be reviewed.

(3) Each facility in Class C shall sustain a static seismic force staying in almost elastic region..

(4) Safety function of an upper-level facility in each item as above should not be damaged by influence of lower level facility

[Detailed note on requirements] <Internal Rules of the NRA>

(1) The postulated contents of the seismic design policy are interpreted as follows:

① Development of the elastic design earthquake ground motion

Each facility in Class S is required “to sustain a seismic force staying in almost elastic region” and this elastic design earthquake ground motion shall be developed based on the engineering judgment. The elastic condition is the one that enables the effect of the earthquake ground motion on a facility and the facility condition to be clearly evaluated. The safety functions of the facility are firmly ensured against a seismic force due to the standard seismic motion by grasping that the facility remains generally in almost the elastic condition against a seismic force due to the elastic design earthquake ground motion.

The specific value and the estimation basis of the elastic design earthquake ground motion are required to be sufficiently clarified for each application. And the response spectrum ratio (elastic design earthquake ground motion/standard seismic motion) of the elastic design earthquake ground motion to the standard seismic motion is requested to be large to a certain extent and it shall have been found as a value not below 0.5 as a standard.

② With regards to a facility in Class B, if the facility that may cause resonance to occur, its effect shall be studied" and the earthquake ground motion used for this study shall be found by multiplying the elastic earthquake ground motion by 1/2.

③ "Those belonging to an upper-level classification shall not lose their safety functions due to the ripple effect of those belonging to a lower-level classification.

At least the following items shall be confirmed in such a way that they have no impact on safety functions. In addition, with regards to the evaluation of an impact, event selection and the results of impact evaluation shall be adequate including the contents of investigation and review, etc. from a bird's eye view of the site. Moreover, the ground motions or seismic forces for the facility of a higher class shall be used to evaluate the impacts.

i) An impact caused by relative displacement or uneven subsidence, etc. due to differences in the established grounds, the behavior of seismic responses, etc.

ii) Mutual impact at the connection part between a higher class and a lower class

iii) An impact on a higher class due to the damage, tipover, drop, etc. of a lower class inside the building

iv) An impact on a higher class due to the damage, tipover, drop, etc. of a lower class outside the building

(2) Seismic force calculation

A seismic force used for the seismic design of a facility shall be calculated by the methods as shown below.

① Seismic force by an analysis of seismic responses

A seismic force by an analysis of seismic responses shall be calculated by the methods as shown below.

i) Seismic force by the standard seismic motion

A seismic force by the standard seismic motion shall be calculated as a proper combination of the two horizontal directions and the vertical direction using the standard seismic motion. Note that the interaction among buildings/structures and soils, the effect of filling, and the nonlinear nature of the surrounding soils shall be taken into account when needed.

ii) Seismic force by the elastic design earthquake ground motion

The elastic design earthquake ground motion shall be set up by the engineering judgment based on the standard seismic motion. A seismic force by the elastic earthquake ground motion shall be calculated as a proper combination of the two horizontal directions and the vertical direction. Note that the interaction among buildings/structures and soils, the effect of filling, and the nonlinear nature of the surrounding soils shall be taken into account when needed.

iii) Analysis of seismic responses

When the seismic forces by the standard seismic motion and elastic design earthquake ground motion are calculated, an appropriate analytical method shall be selected with the applicability of an analytical method of seismic responses, the applicable limit, etc. taken into account. In addition, appropriate analytical conditions shall be set up.

The input seismic motion that is evaluated by the established position of buildings and structures, etc. in the calculation process of the earthquake ground motion shall properly take into account the properties of a dynamic deformation related to nonlinear responses of the soil when needed and the propagation effects of the earthquake ground motion from the base stratum. In addition, the adequacy of this action shall be proven on the basis of the observation records of the site and the latest knowledge and findings.

② Static seismic force

A static seismic force shall be calculated by the methods as shown below.

i) Buildings and structures

A horizontal seismic force shall be calculated by multiplying seismic layer shearing force coefficient C by a coefficient in accordance with the importance classification of a facility as shown below, and additionally by the weight equal to or more than the layer concerned.

Class S 3.0
Class B 1.5
Class C 1.0

Seismic layer shearing force coefficient C_i shall be a value found by setting standard shearing force coefficient C_0 to 0.2 or more and taking into account the vibration characteristics of buildings and structures and soil types.

It shall be needed that the horizontal load-carrying capacity of buildings and structures exceeds the requisite horizontal load-carrying capacity. When the requisite horizontal load-carrying capacity is calculated, a coefficient in accordance with the importance classification of a facility that multiplies the seismic layer shearing force coefficient shall be 1.0 for Classes S, B and C. Standard shearing force coefficient used at this time shall be 1.0 or more. It shall also be confirmed that an adequate safety margin is given in accordance with the importance of a facility.

A facility in Class S shall work even in case that both a horizontal and vertical seismic forces work even with a combination of their disadvantageous directions at the same time. A vertical seismic force shall be based on a seismic intensity of 0.3 or more and calculated from a vertical seismic intensity found in taking into account the vibration characteristics of buildings and structures, soil types, etc. However, a vertical seismic intensity shall be constant in the height direction.

ii) Equipment and piping systems

A seismic force in each seismic class shall be found in such a way that a horizontal seismic intensity results from seismic story shear coefficient C_1 shown in 1) as above multiplied by a coefficient in accordance with the importance classification of a facility. Then, it shall be found from a seismic intensity resulting from the horizontal seismic intensity concerned and vertical seismic intensity in 1) as above added by 20%, respectively. Note that both a horizontal and vertical seismic forces shall work even with a combination of their disadvantageous directions at the same time. However, a vertical seismic intensity shall be constant in a height direction.

iii) Standard seismic story shear coefficient C_0, etc. are set to 0.2 or "more" in i) and ii). This matter is intended for a reactor utilities to properly evaluate the importance of individual buildings and structures as well as equipment and piping systems in their design process and to use an appropriate value for each of them in order to encourage the construction of facilities with high seismic performance, etc. It is important that personnel involved in design and construction takes into account a relationship with the seismic standards of industrial and public facilities, etc. to set up appropriate extra coefficients for the facilities from a viewpoint of an enhancement in resistance to earthquakes.

(3) Combination of loads and allowable limit

The following is a description of the basic concept of combination with loading and an allowable limit when the adequacy of the design policy related to seismic safety is evaluated.

① Buildings and structures

i) Buildings and structures in Class S

a) A combination with the standard seismic motion and an allowable limit

The building and structure concerned shall have a sufficient margin as to deformation capability (deformation at the time of the ultimate strength capacity)) as a whole construction for a combination of loads working at any time, loads working during operation, and a seismic force caused by the standard seismic motion and have an adequate safety margin for the ultimate strength capacity of buildings and structures.

b) A combination with the elastic design earthquake ground motion, etc. and an allowable limit

Loads working at any time and loads working during operation are combined with a seismic force caused by the elastic design earthquake ground motion or a static seismic force resulting in a stress being generated. Then, an allowable stress intensity shall be treated as an allowable limit for this resulting stress according to the norms and standards recognized to be suitable for safety.

ii) Buildings and structures in Classes B and C

Loads working at any time and loads working during operation are combined with a static seismic force resulting in a stress being generated. An allowable stress intensity in ① ii) as above shall be treated as an allowable limit for this resulting stress.

② Equipment and piping systems

i) Equipment and piping systems in Class S

a) A combination with the standard seismic motion and an allowable limit

The functions required for a particular facility shall be kept for the loading condition of combining each loading generated at abnormal transients during normal operation and during operation and accidents with a seismic force caused by the standard seismic motion. If plastic deformation occurs due to loading found by the above procedures, it shall be extremely small and have enough margin to stress limit for cracking and have no effect on the functions required for the facility. With regards to dynamic equipment, etc., the functions required for the facility shall be kept for responses by the standard seismic motion. Specifically, the function-maintaining acceleration, etc. confirmed by the verification test, etc. shall be treated as an allowable limit.

b) A combination with the elastic design earthquake ground motion, etc. and an allowable limit

A response shall generally remain in almost the elastic situation to the loading condition that combines each load at abnormal transients during normal operation and during operation and at accidents with a seismic force caused by the elastic earthquake ground motion or a static seismic force.

ii) Equipment and piping systems in Classes B and C

Responses as a whole shall generally remain in the elastic situation against the consequent stresses by combining loads under normal conditions, abnormal transient conditions during operation, or accident conditions, with the static seismic forces.

③Tsunami protection facilities and SSCs

ⅰ)Building/structure of class S provided in paragraph 2 “Classification of importance of facilities” item 2 and building /structure in which tsunami protection SSCs are installed shall have a sufficient margin as to deformation capability (deformation at the time of the ultimate strength capacity)as a whole construction for a combination of working loading at any time, loading to work during operation and a seismic force caused by the standard seismic motion and have an adequate safety margin for the ultimate strength capacity and shall keep their safety functions (tsunami protection, inundation protection).

ⅱ) SSCs of class S provided in paragraph 2 “Classification of importance of facilities” item 2 shall keep its safety functions(inundation protection and tsunami Monitoring) for a combination of working loading at any time, loading to work during operation and a seismic force caused by the standard seismic motion.

ⅲ） Regarding combination of loading mentioned in above ③ ⅰ） and ⅱ）, investigation on possibility of simultaneous earthquake and tsunami effect shall be conducted. If necessary, combination of seismic force by the standard seismic motion and loading by tsunami shall be considered.

④The contents provided with regards to a loading combination and an allowable limit shall be interpreted as follows:

i) With regards to “each load that is generated at abnormal transients during normal operation and during operation and at accidents,” even in case that loading to work by an event that may be caused by an earthquake and an event that may not be caused by an earthquake, loading due to an event that continues for a long period of time if an accident occurs shall be taken into account by combining with an appropriate seismic motion based on a relationship among the probability and duration of an accident event to occur and the exceedance probability of a seismic motion.

ii) An allowable limit for a combination with the elastic design earthquake ground motion of buildings and structures shall be treated as an “allowable stress according to the norms and standards recognized to be appropriate for safety,” but specifically, this matter corresponds to the Building Standard Law, etc.

iii) The “ultimate strength capacity in the item for a combination with the standard seismic motion of buildings and structures refers to the fact that when loading is gradually increased for structures, the situation that deformation or strain of structures is remarkably increasing. This situation is considered to be the ultimate situation of structures and the ultimate strength means the maximum load of a limit leading to this situation.

iv) The basic concept of the allowable limit against a combination of the elastic design earthquake ground motions, etc., for the equipment and piping systems is to ensure that the “responses as a whole shall generally remain in the elastic situation”. Specifically, the “Technical Requirements (Standards) for Nuclear Power Generation Equipment”[※] provided in the Electric Utilities Industry Law and so on correspond to this matter.

(※)

The current description lists the contents similar to those of the requirements by the Seismic Design Guidelines, but the articles corresponding to the generated stress or the same level of safety as the yield stress. Specifically, the “Technical Requirements (Standards) for Nuclear Power Generation Equipment”[※] provided in the [Electric Utilities Industry Law]” will be quoted in the future.

<The following are major references.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)

- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)

5. Considerations Regarding Ground Stability

【Basic Requirements】<Standard for Establishment License >

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 its safety function by earthquake-induced abnormal conditions of surrounding ground, abnormal conditions such as subsidence uneven among buildings and structures (uneven settlement), liquefaction, consolidation settlement ,etc.

【Detailed Note on Requirements】<Internal Rules of the Nuclear Regulation Authority (NRA)>

- Regarding to the support capacity of the foundation grounds of buildings/structures that support Class S components and systems, in addition to confirming that there is no outcrop of faults on which movements may occur in future as required by “1. Basic Policy Regarding Design against Earthquake and Tsunami”, it shall be confirmed that there is no slip on any weak plane against the ground motions and that the supporting capacity against the standard ground motions is ensured.
- “Tilt and folding of bearing ground (supporting soil) caused by crustal movement due to earthquake” of Paragraph 2 include those caused by wide-area ground upheaval and subsidence as well as local ground upheaval and subsidence. Among these, local phenomena of the tilt and folding of bearing ground may largely affect the safety and therefore particular consideration should be paid.

<The following are major references.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)

6. Formulation of Design Basis Tsunami

【Basic Requirements】<Standard for Establishment License> Design basis tsunami used for facilities safety design shall be appropriate one 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 earthquake and other factors, such as landslide 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 design basis tsunami.

【Detailed Note on Requirements】<Internal Rules of the NRA>

(1) Characteristics of design basis tsunami

Design basis tsunami is the tsunami on the assumption of which tsunami countermeasures are developed to ensure facility safety. It shall be determined through numerical calculations based on tsunami sources which are supposed to cause the most significant impact on the facilities among scenario tsunami sources, as stated in (2).

When providing time history waveform as the design basis tsunami, that of off shore from the site should be adopted, to minimize the influence of reflective wave from the facility, considering feature of submarine topography in front of the site.

Before determining design basis tsunami, its validity shall be adequately checked in the light of the latest knowledge available at the time of individual safety reviews.

(2) Policies for determining design basis tsunami

① The factors stated below shall be taken into account as tsunami-generating factors. Multiple tsunami-generating factors that may significantly affect site shall be selected. Based on site's geological background related to tsunami-generating factors, inter-plate earthquake and other types of earthquake or the combination of earthquake and landslide or the combination of earthquake and slope failure shall be taken into account.

- Interplate earthquake
- Oceanic intraplate earthquake
- Crustal earthquake due to offshore-area active fault

・Onshore/ submarine landslide and slope failure

・Volcanic phenomena (eruption, the collapse of volcanic edifice, caldera subsidence, etc.)

② Appropriate scale of tsunami sources shall be assumed based on plate geometry, slip deficit distribution, fault geometry, topography, geological features, locations of volcanoes, etc. In so doing, domestic and overseas large-scale tsunami as well as similarity in tsunami generation mechanism and tectonic background shall be taken into account. Moreover, far-field tsunami shall be examined taking into account its domestic and overseas examples.

③ With regard to interplate earthquake, earthquake with source area ranging from the lower limit of seismogenic zone depth to trench axis shall be taken into account.

④ If offshore water level changes due to large-scale tsunami that occurred in other regions have been recorded so far, affect to design basis tsunami shall be examined if necessary, while taking into account tsunami generation mechanism, tectonic background similarities, and observed offshore topographical effects.

⑤ The run-up height of design basis tsunami shall exceed those estimated based on geological evidences such as tsunami deposits at site-surrounding area, historical records, etc.

Furthermore, in case administrative organization already evaluate tsunami around or near the site, detail investigation on difference in concept of tsunami source setting and analysis condition etc., should be conducted and effective scientific and technical knowledge should be picked up and be incorporated to formulation of design basis tsunami , in view point of conducting conservative evaluation.

⑥ To add adequate safety margin to anti-tsunami design, when considering uncertainties involved in design basis tsunami determination process, appropriate method shall be used while taking into account the following: tsunami source characteristics-related uncertain factors deemed to significantly affect design basis tsunami determination (factors such as fault's location, length, width, strike, dip angle, slippage, rake, slip distribution, rupture starting point and rupture propagation velocity), the extent of the uncertain factors, and uncertainties resulting from difference in concept and interpretation regarding them.

⑦ The range of tsunami investigation shall be set much wider than that set for a seismic motion assessment. Literature investigation, geomorphological investigation, geology survey, and geophysical survey shall be utilized and appropriately combined in accordance with the topographical and geological characteristics of area to be researched. In addition, researches regarding tsunami-generating factors, those necessary for tsunami source modeling, those regarding tsunami that may have attacked site vicinity, those regarding tsunami propagation path and those necessary for sediment transport assessment shall be carried out.

⑧ Investigations and assessments carried out to determine design basis tsunami shall take into account the latest scientific and technological knowledge. With the range of each investigation taken into account, existing reference materials and literature shall be referred to while adequately examining their sufficiency level and accuracy. When obtaining results different from existing assessment results, the reason for such difference shall be clearly presented.

⑨ The exceedance probability of determined design basis tsunami shall be grasped by referring to applicable exceedance probability.

(Reference)

"Refer to" means to recognize the possibility of events that may exceed the severity of determined design basis tsunami as described in the (Reference) of Detailed Note on Requirements of "1. Basic Policy Regarding Earthquake and Tsunami." Based on such recognition, when designing facilities, due consideration shall be paid and effort for reducing "residual risks" shall be continually made during and after basic design development stage.

<The following are major reference materials.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Severe Accident Measures at Light Water Nuclear Power Reactor Facilities (Basic Policy for Ensuring the Safety of Reactor Facilities Against Beyond-Expectation Tsunami) (March 12, 2012)

7. Design policy against tsunami

【Basic Requirements】<Standard for Establishment License>

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 design basis tsunami:

1. A site where facilities provided in paragraph 2 “Classification of Importance of Facilities” item 1,having important safety functions, are located shall prevent design basis tsunami from directly reaching and intruding into them through land area. Moreover, water intrusion into 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. Other than flood protection measures stated in subparagraph (2), flood protection measures for facilities provided in paragraph 2 “Classification of Importance of Facilities” item 1,,having important safety functions, shall be taken to isolate them from tsunami effect.

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 provided in paragraph 2 “Classification of Importance of Facilities” item 2, 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 (scouring, sediment transport, debris flow, etc.) shall be taken into account.

【Detailed Note on Requirements】< Internal Rules of the NRA>

(1) With regard to Subparagraph 1 of the Basic Requirements, the policies shown below shall be satisfied. These requires measures for preventing tsunami from reaching and intruding into site as basical policy. These policies are provided as design policies for ensuring safety against the possibility of the following events and safety-related uncertainties that increases as site water intrusion spreads.

- Occurrence of debris flow as a result of seawater intrusion and discharge; accompanied effects of debris flow on tsunami protection facilities and systems as well as outdoor systems(components and piping); Lowering of site accessibility due to the above phenomena
- Occurrence of ground abnormality such as foundation scouring in the vicinity of structures, and liquefaction during aftershock (with consideration of possibility of uplift of underground water levels dued to inundation of nearby grounds), lowering of site accessibility due to ground abnormality, and accompanied effects on tsunami protection facilities and underground structures

① Buildings containing SSCs that have important safety functions and outdoor SSCs that have important safety functions shall be located at adequately high places so that wave run-up caused by design basis tsunami will not reach them.

If such buildings and SSCs are located at places where run-up wave may reach, tsunami protection facilities such as tide embankment shall be installed.

② To prevent the intrusion of run-up wave mentioned in ①, the possibility of wave run-up to the site shall be examined by taking into account the topography and the altitude of the site and site vicinity, the presence/absence of river, earthquake-induced wide-area upheaval & subsidence and run up wave running around in. If changes of topography and the courses of rivers are expected due to earthquake-caused deformation as well as scouring and deposition due to repeatedly attacking tsunami, their effect on tsunami run-up routes leading to the site shall be examined.

③ Possibility of water intrusion into facility through intake and discharge channel etc. should be investigated and probable intrusion path (door, opening, penetration etc.)should be identified. Tsunami intrusion should be prevented by measure on these intrusion paths.

(2) With regard to Subparagraph 1 of the Basic Requirements, the following policies shall be satisfied.

① Taking into account of feature of structure of intake/discharge facilities, the possibility of water leakage through any paths from water intake/discharge facilities and underground parts shall be examined. Based on such examination, range where flooding is assumed due to continuous water leakage (hereinafter referred to as potential flooded range) shall be identified. At the same time, routes and inlets from where floodwater may intrude (door, opening, penetration, etc.) at the boundary of the potential flooded range shall be restricted by providing them with water intrusion countermeasures.

② When systems and equipment having important safety functions are located in the vicinity of potential flooded range, the location shall be compartmentalized to make it watertight. When necessary, the amount of floodwater shall be assessed and whether the amount affects such safety functions shall be checked.

③ If long-term inundation is expected at the potential flooded range, drainage system and equipment shall be installed.

(3) With regard to Subparagraph 3 of the Basic Requirements, the policy below shall be satisfied. The policy below can be attained by accomplishing the requirements of Subparagraphs 1 and 2 (outer ward protection) of the Basic Requirements, prevention of water intrusion into the site due to design basis tsunami, and in addition, requires intensively protecting buildings/ compartments containing SSCs having safety functions (inner ward protection) .

These requirements of Subparagraphs 1 to 3 of the Basic Requirements provide multiplex design basis tsunami protection and isolate safety functions from tsunami effects as far as possible, thereby preventing damage to them. Moreover, these provide inner ward protection to protect SSCs having safety function against synergistic effects due to earthquake and tsunami, such as flooding due to damage to circulatory system piping, tank, etc. inside site and buildings and groundwater intrusion due to drain system pump stop in subclass buildings caused by earthquake and tsunami.

① Buildings and compartments containing SSCs having important safety functions shall be clarified as a range requiring intensive anti-inundation protection, and be identified routes and inlets (door, opening, penetration, etc) in the range of requiring intensive anti-inundation protection, from which floodwater may intrude , assuming inundation range and quantity conservative due to inner and outer flooding caused by earthquake and tsunami, Moreover, be provided with anti-inundation measures against these routes and inlets.

(4) With regard to Subparagraph 4 of the Basic Requirements, the following policy shall be satisfied.

① With regard to emergency seawater cooling system, its seawater pumps shall be designed to keep function against drawdown (water level decrease) caused by design basis tsunami and to intake seawater necessary for cooling. A seawater intake port (inlet) shall not be clogged by the transport and deposition of sand and debris generated due to water level fluctuation caused by design basis tsunami. Also seawater pumps shall keep function against sand intrusion from intake.

(5) With regard to Subparagraph 5 of the Basic Requirements, the following policies shall be satisfied.

① Tsunami protection facilities mean tide embankment, banking structure, flood barrier, etc. Tsunami protection SSCs mean watertight doors and SSCs for preventing water intrusion into openings and penetrations.

Tsunami monitoring SSCs mean tide gauges, sea water intake pit level meter and outside monitoring camera watching tsunami attacking situation etc.

Other than these, tsunami impact-reducing facilities and SSCs shall be installed, such as breakwater, which can be expected to mitigate wave power exerted on tsunami protection facilities.

② Input tsunami used to design tsunami protection facilities/SSCs and tsunami monitoring SSCs etc. shall be numerically calculated as time history wave at the location of each facility and SSC, using tsunami source for design basis tsunami.

At numerical calculation of input tsunami time history, followings should be taking into account that site configuration/contour, the submarine topography of site coastal zone, the angle of tsunami intrusion into site, presence/absence of river, onshore tsunami run-up, propagation effect and artificial structure on the propagation path , etc. And activation of local natural frequency oscillation mode of sea water surface inside the bay shall be appropriately considered and evaluated.

③ A tsunami protection facility shall be assessed, according to its structure, for resistance against corrosion and scouring by wave force and stability against slipping and tip-over in order to design it capable of maintaining adequate tsunami protection function against input tsunami.

④ A tsunami protection facility shall be assessed for its durability against wave pressure during water intrusion and after being flooded at its potential flooded range in order to design it capable of adequately maintaining its water intrusion prevention function against design basis tsunami.

⑤ Tsunami monitoring SSCs shall be designed so that it keep tsunami monitoring function adequately against input tsunami, investigating appropriate location not easily affected, measure for prevention and mitigation against tsunami effect (wave force, floating debris impact etc.).

⑥ As for buildings and structures constituting a boundary between tsunami protection facilities/SSCs and potential flooded range, it shall be confirmed that - tsunami protection function and water intrusion prevention function are ensured against earthquakes (main shock and aftershocks) by taking into account of impacts of the design basis ground motions. If a building, structure or installation may suffer damage, collapse or drift at plant site outside tsunami protection facilities or at site vicinity, drift prevention measures or measures for preventing impact on tsunami protection facilities such as tide embankment shall be taken to prevent spillover effect on them.

⑦ When designing facilities, SSCs, etc. in accordance with ③, ④and ⑥,

an adequate tsunami safety margin shall be added to them. Therefore, loads expected during functional impairment mode of each facility and SSC (loads such as inundation height, wave power, wave pressure, scour power, buoyant force) shall be set with its durability during overflow and adequate safety margin against input tsunami taken into account.

Investigation on possibility of aftershock should be conducted and if necessary, combination of loading by aftershock and input tsunami should be considered.

Based on the time history wave form of input tsunami, the impact of repetitive tsunami attacks on tsunami protection function and water intrusion prevention function shall be considered.

⑧ When designing tsunami protection facilities and SSCs, the effectiveness of tsunami impact mitigation facilities and SSCs shall be also examined so that they are designed to be able to maintain impact mitigation function against input tsunami and satisfy requirements ⑥, ⑦.

(6) In addition to the above, the following policy shall be satisfied:

In assessing tsunami protection facility/SSC's design and emergency seawater cooling system, water level fluctuation caused by input tsunami shall be also assessed conservatively while taking into account tsunami run-up mean tide level. Moreover, water level fluctuation caused by another factor should be appropriately evaluated and considered. If earthquake-induced onshore upheaval or subsidence is expected, the amount of potential crustal movement at the site calculated through the source model of expected earthquake shall be taken into account to assess them conservatively (on the safe side).

<The following are major reference materials.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Severe Accident Measures at Light Water Nuclear Power Reactor Facilities (Basic Policy for Ensuring the Safety of Reactor Facilities against Tsunami Exceeding Expectation) (March 12, 2012)

8. Design Considerations Regarding the Stability of Surrounding Slope

【Basic Requirements】<Standard for Establishment License>

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.

【Detailed Note on Requirements】<Internal Rules of the NRA>

When assessing the safety of slope surrounding facilities, the following shall be taken into account:

① Slope that may affect buildings where important safety-related SSCs are installed or that may affect important safety-related outdoor SSCs shall be assessed for its stability.

② The safety of slope surrounding facilities shall be assessed while taking into account geological features, ground structure, ground grade/classification, liquefaction possibility, groundwater effect, etc. and by using sliding safety factor.

③ Ground model, ground parameter and seismic force used in assessment shall be estimated based on the assessment of the support capacity of foundation ground. In particular, due consideration shall be paid to groundwater effects.

<The following are major reference materials.>

- Regulatory Guide for Reviewing Seismic Design of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)
- Guide for Seismic Safety Review of Nuclear Power Reactor Facilities (revision draft) (March 22, 2012)