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Analysis of the strong motion records obtained from the 2007 Niigataken Chuetsu-oki earthquake and determination of the design basis ground motions at the Kashiwazaki Kariwa Nuclear Power Plants (Part3: Determination of the design basis ground motions considering findings from the earthquake)

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1 ABSTRACT

The Niigataken Chuetsu-oki earthquake (Mj6.8) occurred on 2007 July 16th, and observation record at the Kashiwazaki Kariwa nuclear power plant exceeded the original design basis ground motion which was determined under the previous guidelines.

We chose the active faults which is thought to have large impacts on the Kashiwazaki Kariwa nuclear power plant, and we evaluated the ground motion by the chosen sources, on the basis of the factors that magnified the earthquake ground motion at the Kashiwazaki Kariwa nuclear power plant in the Niigataken Chuetsu-oki earthquake.

Based on the results of this earthquake ground motion, we determined the new design basis ground motion of the Kashiwazaki Kariwa nuclear power plant.

2 INTRODUCTION

On 2006 September 19th, “the Guidelines for Seismic Design Evaluation of Nuclear Power Reactor Facilities (hereinafter referred to as ‘The seismic guidelines’)” was revised by Nuclear Safety Committee (NSC), which relates to the seismic safety of the nuclear reactor installation in Japan. After the revision, re-evaluation on the seismic safety of the all operating nuclear power plants which includes the determination of the design basis ground motions based on the revised guidelines had been started.

At the Kashiwazaki Kariwa nuclear power plant, re-evaluation of the seismic safety was also being conducted, but the Niigataken Chuetsu-oki earthquake (Mj6.8) occurred on 2007 July 16th, and observation record at the Kashiwazaki Kariwa nuclear power plant exceeded the original design basis ground motion which was determined under the previous guidelines.

On the basis of the circumstance, determination of the design basis ground motion for Kashiwazaki Kariwa Nuclear Power Plants conducted considering the lessons learned from the Niigataken Chuetsu-oki earthquake.

In this paper, we determined the new design basis ground motion on the basis of the factors that magnified the earthquake ground motion at the Kashiwazaki Kariwa nuclear power plant in the Niigataken Chuetsu-oki earthquake, which were examined in the part 1 and the part 2.

3 POLICY ON FORMULATING THE DESIGN BASIS GROUND MOTION

In the seismic guidelines, the design basis ground motion of nuclear power reactor facilities shall be formulated on the following principles.

(1) The design basis ground motion shall be formulated the “Earthquake ground motions with the site specific earthquake source locations” and the “Earthquake ground motions with no such specific source locations”.

(2) The earthquake ground motions with the site specific earthquake source locations selects earthquakes which may have severe impacts to the proposed site, taking account of the characteristics of active faults, etc. (hereinafter referred to as “Earthquakes for investigation”). For each “Earthquakes for investigation” selected, we adopted both the empirical method using response spectrum based on attenuation relation, and the numerical simulation method based on the source fault model, the design basis ground motion shall be formulated on the basis of the evaluation of the chosen sources.

(3) The earthquake ground motions with no such specific source locations shall be formulated by: collecting the observation records near the epicenter which are obtained from the past earthquakes inside the inland earth’s crust, where the correlation of the epicenter and the active faults is difficult to specify; defining the response spectra based on those records.

Figure 1 shows the policy on formulating design basis ground motion of the Kashiwazaki Kariwa nuclear power plant.

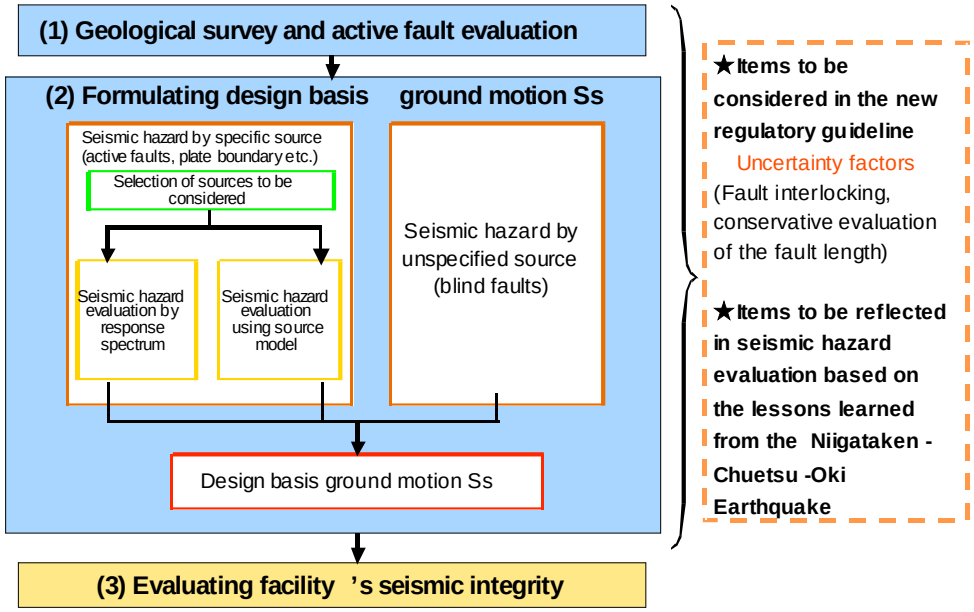


Figure 1. Policy on formulating design basis ground motion

4 REFLECTION OF KNOWLEDGE FROM THE NIIGATAKEN-CHUETSU-OKI EARTHQUAKE

On the basis of the examination result of the part 1 and the part 2, following items (1)-(3) were mainly considered as knowledge which is acquired from the Niigataken Chuetsu-oki earthquake, when the design basis ground motions of the Kashiwazaki Kariwa nuclear power plant were evaluated.

(1)The characteristics of the earthquake ground motion propagated from the offshore sources are different from those propagated from the inland sources. Therefore, we selected the active faults to be evaluated, classifying them into the offshore faults and the inland ones.

(2) The characteristics of the earthquake ground motion propagated from the offshore sources are different between Arahama side (where Unit 1-4 are installed) and Ominato side (where Unit 5-7 are installed).

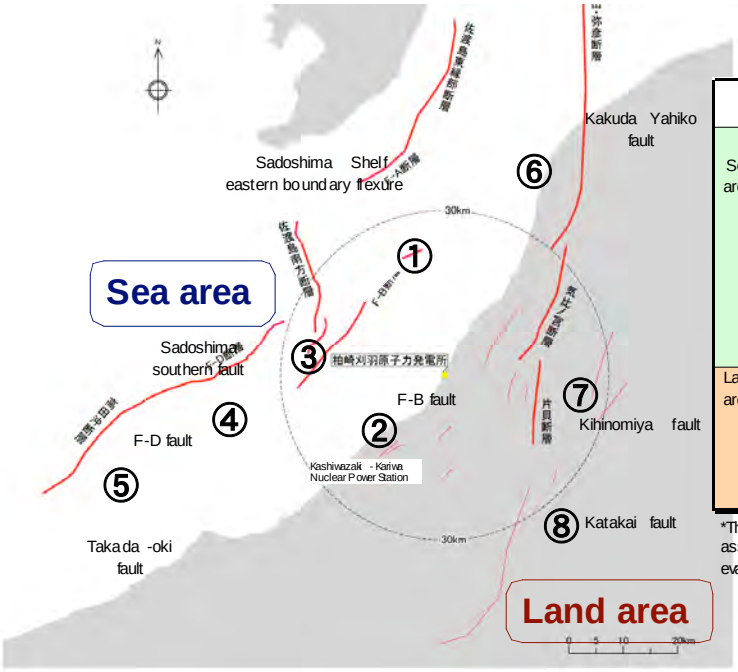
Therefore, we evaluated the design basis ground motions by offshore active faults for Arahama side and in Ominato side separately.

(3) The Niigataken Chuetsu-oki earthquake generated 1.5 times larger ground motion in the short period range in comparison with the average earthquakes of Mj6.8. Therefore, we applied 1.5 times larger short period ground motion level than that of average level to the earthquake ground motion evaluation using the source fault model.

5 EARTHQUAKE GROUND MOTIONS WITH THE SITE SPECIFIC EARTHQUAKE SOURCE LOCATIONS

5.1 Selection of earthquakes for examination

We evaluated active faults around the site based on geological surveys conducted after the Niigataken Chuetsu-oki earthquake. Figure 2 shows an active faults distribution for the area around the site based on results of geological surveys. The scale of earthquakes (magnitude) generated by hypocenter faults set based on the F-B Fault is calculated based on the relationship between the Niigataken Chuetsu-Oki Earthquake hypocenter fault and earthquake scale as shown in the "5.2 Earthquake caused by the F-B Fault 5.2.1 Standard source model" and the scale of earthquakes generated by other active faults are calculated based on the methods proposed by Matsuda (1975).



Major active faults

	Fault name	Fault length
Sea area	(1) Sadoshima Shelf eastern boundary flexure	Approx. 37km
	(2) F-B fault	Approx. 36km *
	(3) Sadoshima Southern fault	Approx. 29km
	(4) F-D fault	Approx. 30km
	(5) Takada -oki fault	Approx. 25km
Land area	(6) Kakuda Yahiko fault	Approx. 54km
	(7) Kihinomiya fault	Approx. 22km
	(8) Katakai fault	Approx. 16km

*This fault is 27km long according to the TEPCO survey, and is assessed to have the length of 36km for the purpose of safety evaluation.

Figure 2. Active faults near the power station

5.2 Earthquake caused by the F-B Fault

5.2.1 Standard source model

The source fault plain of the Niigataken Chuetsu-oki Earthquake is considered to have a fault length of 27km and a dipping angle of 35 deg., according to the source fault model constructed by the Headquaters of Earthquake Research Promotion (hereinafter HERP) and the distribution of its aftershocks.

On the other hand, the F-B fault is considered to have a fault length of 27km based on the result of geological survey and its location corresponds to that of the Niigataken Chuetsu-oki Earthquake's source fault.

So, in the ground motion evaluation of the F-B fault, every source fault parameters are set based on the information acquired from the Niigataken Chuetsu-oki Earthquake, to define the source fault model as a basic source fault model which corresponds to the fault length of 27km.

5.2.2 Consideration of uncertainty of the seismic motion evaluation

Considering the deliberation of the regulatory committee, the fault length of the F-B fault is considered to reach 36km so as to taking into account the uncertainties over the fault length evaluation, though it is considered to be 27km based on the geological survey results. No other uncertainty was taken into account for the other source fault parameters, considering those particular information acquired through the Niigataken Chuetsu-oki Earthquke.

The magnitude for the event caused by the fault is set based on the relation between the magnitude and the source fault plain of the Niigataken Chuetsu-oki Earthquake. The source model of the F-B fault for the fault length of 36km is shown in Fig. 3.

5.2.3 Seismic motion evaluation by response spectrums

During the hypocenter evaluation based on response spectrum of the F-B Fault earthquake, since the observation records of the Niigataken Chuetsu-oki earthquake was obtained from the reactor building foundation plate, by considering the comparison of the seismic motion of the free surface of the base stratum estimated based on the reactor building foundation plate observation records with the response spectrums proposed by Noda et al. (2002) (hereinafter referred to as “site correction coefficient ”), we reflected each attribute such as the effect of the underground structure of the site.

This site correction coefficient was set to envelop the comparison of the free bedrock wave estimated from the observation records from each unit with the response spectrum's proposed by Noda et al. (2002). Figure 4 shows the horizontal site correction coefficient.

5.2.4 Seismic motion evaluation by fault model

During seismic motion evaluation based on methods that use fault models of the F-B Fault earthquake, by using the empirical Green’s function [Dan et al. (1989)] that uses aftershocks from the Niigataken Chuetsu-oki earthquake generated in an envisioned hypocenter region as the element earthquake, we consider an elemental attributes such as the effect of the underground structure of the site.

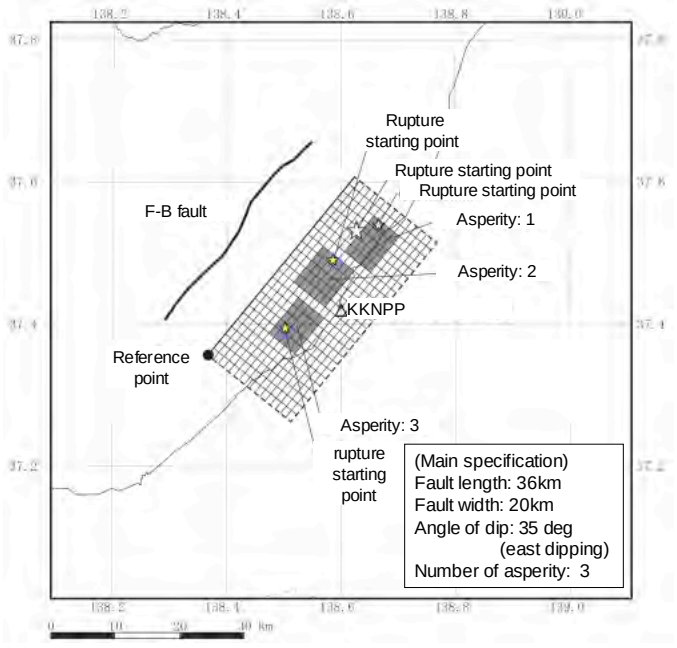


Figure 3. Source fault model of F-B fault (fault length: 36km)

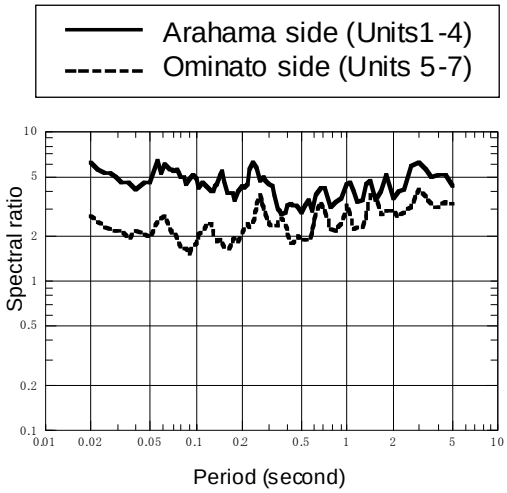


Figure 4. Site correction used with response spectrum method of F-B fault (Horizontal)

5.3 Earthquake caused by the Katakai Fault

5.3.1 Standard source model

Parameters for the basic source fault model of the Katakai fault were mainly set based on the information from the result of the geological survey and the report titled “the recipe for strong motion prediction” by HERP (hereinafter the “recipe”).

Regarding the fault length, it was set at 25km, which is consistent with the area of the source fault plain that saturates the seismogenic zone, referring the recipe from the view point of the scaling of earthquake magnitude, although it is evaluated as 16km according to the result of the geological survey.

5.3.2 Consideration of uncertainty of the seismic motion evaluation

In order to evaluate the ground motion of the Katakai Fault, we considered the uncertainties of the source parameters which were shown below.

(a.)Fault length

Activity of Katakai fault is standard case, and we considered the Nagaoka Plain Western Boundary fault Zone (Fault length is 91km) which is the fault interlocking with its surrounding faults (Kihinomiya fault, Kakuda-Yahiko fault).

(b)Rupture starting point

Place which rupture proceed toward the site is the standard case, and boundary of asperity is also considered as an uncertainty

(c)The location of asperity

Upper-center position of the fault plain is the standard case, and lower-center is also considered.

(d)Fault dipping angle

50 deg. is the standard case according to the evaluation of Headquarters for Earthquake Research Promotion (2004) , and 35 deg. is also taken into account as an uncertainty.

(e)The amount of stress drop

On the basis of the lessons learned from the Niigataken Chuetsu-oki earthquake, 1.5 times larger than recipe is considered

Furthermore, as a more conservative evaluation, ground motion evaluation considering uncertainties of the fault length & stress drop simultaneously, and fault length & dipping angle simultaneously, which have larger impact, is conducted.

Among the cases which were examined for the seismic motion evaluation of the Katakai Fault, Figure 5 shows the case which was considering uncertainties of the and fault length & dipping angle simultaneously.

5.3.3 Seismic motion evaluation by response spectrums

During evaluation of seismic motion based on the response spectrum of earthquakes caused by the Katakai fault, since observation records from earthquakes generated in land areas (Chuetsu region) in the same direction as the envisioned earthquake have been obtained from the site, by using the comparison of the free bedrock wave estimated based on these observation records and the response spectrums proposed by Noda et al. (2002), each attribute from the effect of the underground structure of the site, for example, was considered.

Furthermore, whereas this site correction coefficient based on the observation records falls below 1 on the short cycle side less than cycles of 1 second, or safety evaluation reasons for the limit of the response spectrum comparison has been set at 1. Figure 6 shows the horizontal site correction coefficient.

5.3.4 Seismic motion evaluation by fault model

During seismic motion evaluation based on methods that use fault models of Katakai fault earthquakes, by using the empirical Green’s function [Dan et al. (1989)] that uses aftershocks from the Niigataken

Chuetsu earthquake of 2004 generated in the same direction in a land area (Chuetsu region) as the envisioned earthquake, we consider an elemental attributes such as the effect of the underground structure of the site.

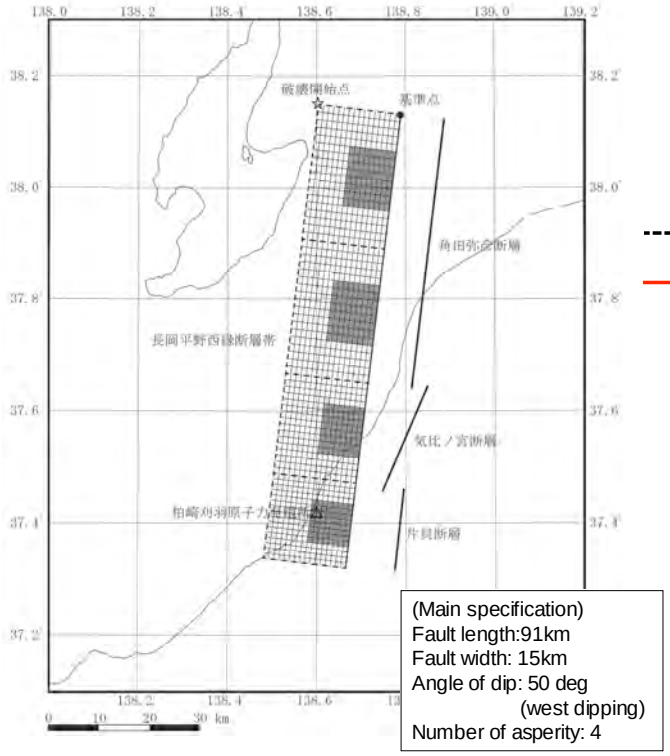


Figure 5. Source fault model of Katakai fault (The case considering uncertainty of the fault length & dipping angle:Nagaoka Plain Western Boundary fault Zone)

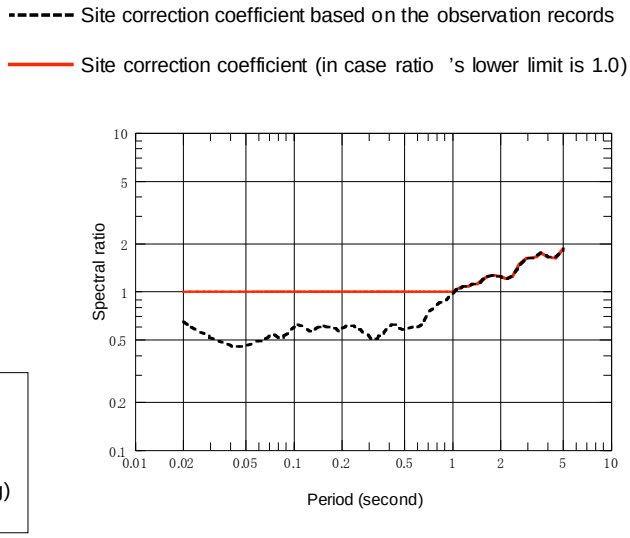


Figure 6. Site correction used with response spectrum method of Katakai fault (Horizontal)

5.4 Determination of the design basis ground motion

As the new design basis ground motions for Kashiwazaki Kariwa nuclear power plant, we determined the design basis ground motion Ss-1 - Ss-5, on the basis of the result of seismic motion evaluation by response spectrums and seismic motion evaluation by fault model, which were examined in “5.2 Earthquake caused by the F-B Fault ” and “5.3 Earthquake caused by the Katakai Fault”.

Ss-3 was defined so as to envelop both cases, the one considering uncertainties about the fault length and the stress drop of the asperities simultaneously, and the other considering uncertainties about the fault length and the dipping angle of the fault plain simultaneously, because evaluated ground motion level for each case dominates in different frequency range.

We determined the design basis ground motion Ss-1 - Ss-5 of horizontal direction and vertical direction. Figure 7 shows the response spectrum horizontal of horizontal direction.

Table 1 shows the maximum peak value of acceleration time histories that were evaluated, on the basis of the response spectrum by the design basis ground motion Ss-1 - Ss-5.

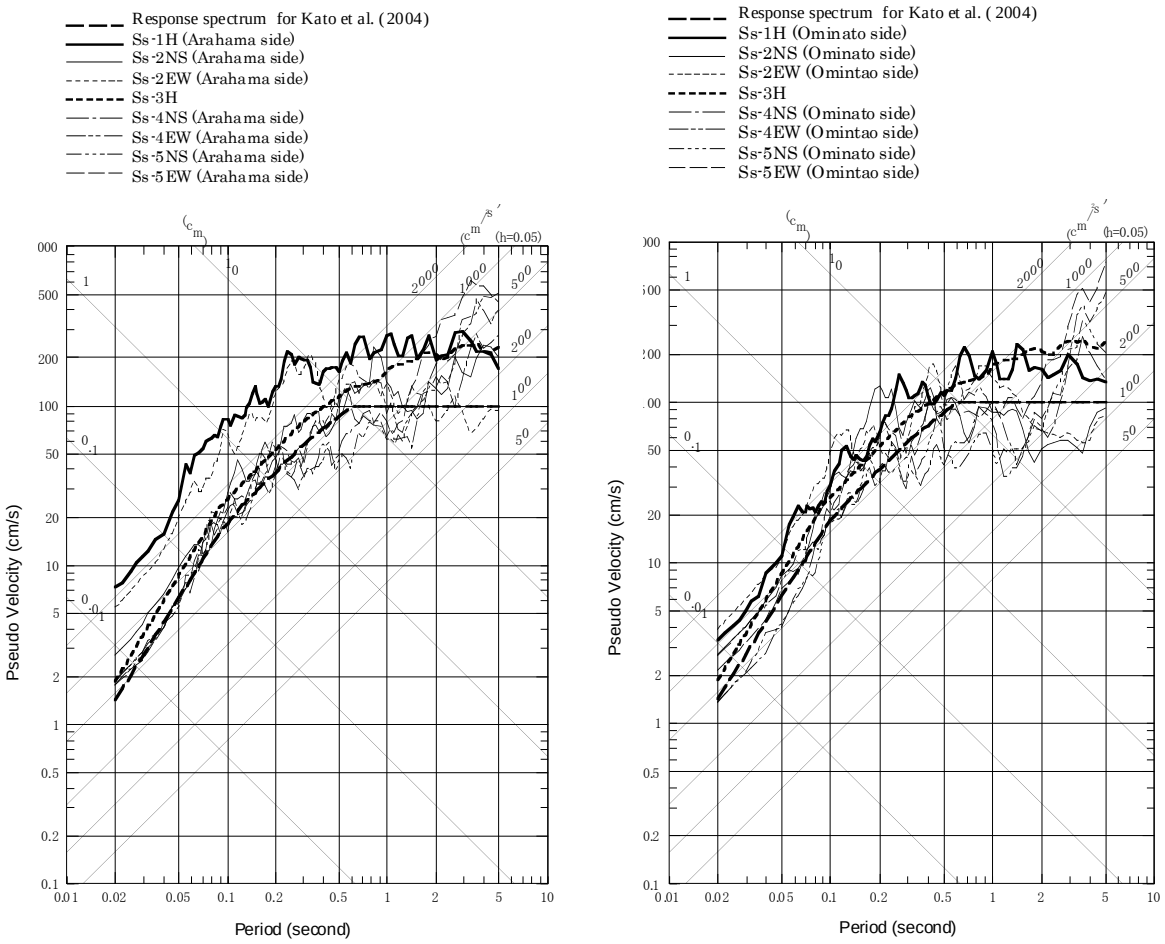


Figure 7. Comparison of the design basis ground motion Ss-1-Ss-5 and response spectrum for Kato et al. (2004) (Horizontal)

Table 1. Maximum peak acceleration value of the design basis ground motion Ss-1-Ss-5

(Unit: Gal)

Design basis ground motion	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
Ss－1 (F-B fault / Response spectrum for Noda et al.(2002))	Horizontal: 2 300 Vertical: 10 50				Horizontal: 10 50 Vertical: 6 50		
Ss－2 (F-B fault / Empirical Green's function)	NS: 847 EW: 1703 UD: 510				Ns: 848 EW: 1209 UD: 466		
Ss－3 (Nagaoka plain western boundary fault zone / Response spectrum for Noda et al.(2002))	Horizontal: 600 Vertical: 400						
Ss－4 (Nagaoka plain western boundary fault zone / Empirical Green's function)	N S 589 EW 574 UD 314				N S 428 EW 826 UD 332		
Ss－5 (Nagaoka plain western boundary fault zone / Empirical Green's function)	N S 553 EW 554 UD 266				N S 426 EW 664 UD 346		

6 EARTHQUAKE GROUND MOTIONS WITH NO SUCH SPECIFIC SOURCE LOCATIONS

For inland inner-crustal earthquakes, Kato et al. (2004) proposes a horizontal motion response spectrum for a free surface of the base stratum with an S wave velocity of 0.7km/s that adds the ground attributes of the site based on strong motion records for rigid ground around the hypocenter of earthquakes for which the hypocenter location and magnitude cannot be specified in advance even through detailed geological surveys.

Figure 7 shows a comparison of the response spectrum for Kato et al. (2004) and the response spectrum for the design basis ground motion Ss-1-Ss-5. According to Figure 7, since the response spectrum for Kato et al. (2004) fall below the design basis ground motion Ss-1-Ss-5 in all cycle bands, the design basis ground motion from “Earthquake ground motions with no such specific source locations” can be used to represent the design basis ground motion Ss-1-Ss-5 from “Earthquake ground motions with the site specific earthquake source locations”.

7 CONCLUSIONS

As the new design basis ground motions for Kashiwazaki Kariwa nuclear power plant, we determined 5 earthquake ground motions on the basis of the evaluation of the chosen sources. Peak ground acceleration (PGA) value of the design basis ground motions for horizontal component is 1,209Gal at Arahama side, and is 2,300Gal at Ominato side. PGA) value of the design basis ground motions for vertical component is 1,050Gal at Arahama side, and is 650Gal at Ominato side.

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