A report on anti-earthquake countermeasures of the switchyard etc. with a view to securing reliability of offsite power supply for Nuclear Power Stations etc.

July 7, 2011

Tokyo Electric Power Company

1. Preface

Further to the damages to the Air Blast Circuit Breakers etc. at the switchyard within Fukushima Daiichi Nuclear Power Station by Tohoku-Chihou-Taiheiyo-Oki Earthquake occurred on March 11, 2011, Nuclear and Industrial Safety Agency (“NISA”) of Ministry of Economy, Trade and Industry issued an instruction notice “Regarding the anti-earthquake countermeasures of the switchyard etc. with a view to securing reliability of offsite power supply for Nuclear Power Stations etc. (direction)” (June 7, 2011 Nuclear Number 1). As per that instruction notice, this is to report on the status of the evaluation regarding the possibility of collapse, damage etc. to the electrical facilities such as switchyards at our Nuclear Power Station.

2. Directions

(1) Based on the analysis of the earthquake observation record at Fukushima Daiichi Nuclear Power Station at the time of Tohoku-Chihou-Taiheiyo-Oki Earthquake in 2011, evaluate the possibility of collapse, damage etc. to the electrical facilities such as switchyards at our Nuclear Power Station.

In doing this, set the earthquake load at the ground level at each nuclear power station etc., analyze the stress at electrical facilities, compare the stress with the structural strength of those facilities and evaluate.

(2) If the above evaluation (1) results in “yes”, set out the anti-earthquake countermeasures for those facilities.

3. Damages to facilities at Fukushima Daiichi Nuclear Power Stations by Tohoku-Chihou-Taiheiyo-Oki Earthquake and analysis of the earthquake observation result

(1) Damages to facilities at Fukushima Daiichi Nuclear Power Stations by Tohoku-Chihou-Taiheiyo-Oki Earthquake

There were damages to the Power Receiving Circuit Breaker for Okuma Line #1, for Unit 1 and the Power Receiving Circuit Breaker and the Power Receiving Line Switch for Okuma Line #2, for Unit 2 by Tohoku-Chihou-Taiheiyo-Oki Earthquake that occurred at 2:46 pm, on March 11, 2011.

(2) Analysis of the earthquake observation result at Fukushima Daiichi Nuclear Power Station by Tohoku-Chihou-Taiheiyo-Oki Earthquake

There is no observation record of acceleration at those Circuit Breakers etc. We observed 258～460 for Unit 1 and 302～550 for Unit 2 as the maximum acceleration for NS, EW, UD directions at the base mat of Reactor Building, Fukushima Daiichi Nuclear Power Station. We also observed 326～600 at the south point and 239～699 at the north point as the maximum acceleration for NS, EW, UD directions at the surface level of Free Base.

4. Our facilities subject to evaluation

Given damages to Circuit Breakers etc. at Unit 1 & 2, Fukushima Daiichi Nuclear Power Station, we evaluate similar switchyard facilities at our Nuclear Power Stations (table 1). Also, there are step-down transformers (table 2) that lower the voltage after receipt of power at switchyard facilities. As those transformers are large equipments, we likewise evaluate those to confirm those do not collapse or overturn in the event that strong exciting force is applied to them by an earthquake.

Table 1: Facilities subject to evaluation at switchyards of our Nuclear Power Stations

Power Station	Unit	Voltage	Type
Kashiwazaki Kariwa Nuclear Power Station	1～7	500kV	GIS
		154kV	ACB (gas)
		66kV	GIS
Fukushima Daini Nuclear Power Station	1～4	500kV	GIS
		500kV	ACB (air)
		66kV	GIS
		66kV	ACB (gas)

Table 2: Transformers subject to evaluation at our Nuclear Power Stations※

Power Station	Unit	Name of transformers	Voltage
Kashiwazaki Kariwa Nuclear Power Station	1～7	HV Start-Up Transformer #1 (Unit 1)	500/66kV
		HV Start-Up Transformer #2 (Unit 5)	500/66kV
		HV Start-Up Transformer #3 (Unit 4)	500/66kV
		Auxiliary transformer	154/66kV
	1	LV Start-Up Transformer (A)	66/6.9kV
		LV Start-Up Transformer (B)	66/6.9kV
	3	LV Start-Up Transformer (A)	66/6.9kV
		LV Start-Up Transformer (B)	66/6.9kV
	5	LV Start-Up Transformer (A)	66/6.9kV
		LV Start-Up Transformer (B)	66/6.9kV
	6	LV Start-Up Transformer (A)	66/6.9kV
		LV Start-Up Transformer (B)	66/6.9kV
Fukushima Daini Nuclear Power Station	1～4	HV Start-Up Transformer	500/66kV
	1	LV Start-Up Transformer (A)	66/6.9kV
		LV Start-Up Transformer (B)	66/6.9kV
	3	LV Start-Up Transformer (A)	66/6.9kV

		LV Start-Up Transformer (B)	66/6.9kV

※Those transformers are to receive offsite power supply

5. Evaluation method for switchyard facilities

At Nuclear Power Stations, switchyard facilities and transformers are classified as "Class C" i.e. the required aseismic capacity is the same as general industrial facilities. However, as we observed a peak between 0.5Hz～10Hz of the earthquake response spectra that coincides with the sympathetic vibration frequency of insulator facilities, we first evaluate by JEAG5003 (Anti-earthquake designing guideline for electrical facilities at substations etc.) that takes account of the earthquake response spectra and the sympathetic vibration in order to confirm the safety ratio in design.

(1) Switchyard facilities

We applied three-phase resonant sinusoidal wave ($3 m/s^2$) to the bottom of equipments for dynamic appraisal. This is derived from (i) two-phase resonant sinusoidal wave ($3 m/s^2$) to the ground level times (ii) 1.2 to account for the acceleration by the existence of base and (iii) 1.1 for unknown factors such as vertical acceleration and the effect by the bonding conductor.

The assumed acceleration level at the surface of the ground ($3 m/s^2$) covers 98% of earthquakes in the past 75 years. Acceleration amplification factor of 4.7 that corresponds to two-phase resonant sinusoidal wave covers 93% of past large earthquake data and 6.1 for three-phase resonant sinusoidal wave covers almost all.

(2) Transformers

JEAG5003 provides that the transformer will not collapse (foundation bolts will not be sheared) with static force ($5 m/s^2$).

We observed 258～460 for Unit 1 and 302～550 for Unit 2 as the maximum acceleration at the base mat of Reactor Building. We also observed 239～600 as the maximum acceleration at the surface level of Free Base. However, as the transformer's natural frequency is relatively high (>15Hz) and away from the peak of acceleration of the earthquake observation result, we use static force ($5 m/s^2$) for evaluation.

6. Evaluation result

The safety ratios of our switchyard facilities and transformers listed in chapter 4 of this report evaluated per JEAG 5003 are as tables 3 and 4.

Table 3: The evaluation result of switchyard facilities at our Nuclear Power Station

Power Station	Unit	Voltage	Type	Safety ratio※	Part※
Kashiwazaki Kariwa Nuclear Power Station	1～7	500kV	GIS	3.80	Bushing
		154kV	ACB (gas)	2.20	Bushing
		66kV	GIS	2.30	Tank
Fukushima Daini Nuclear Power Station	1～4	500kV	GIS	2.04	Bushing
		500kV	ACB (air)	2.10	Intermediate insulator
		66kV	GIS	3.00	Tank
		66kV	ACB (gas)	2.70	Pedestal

※ This table indicate parts with lowest safety ratio

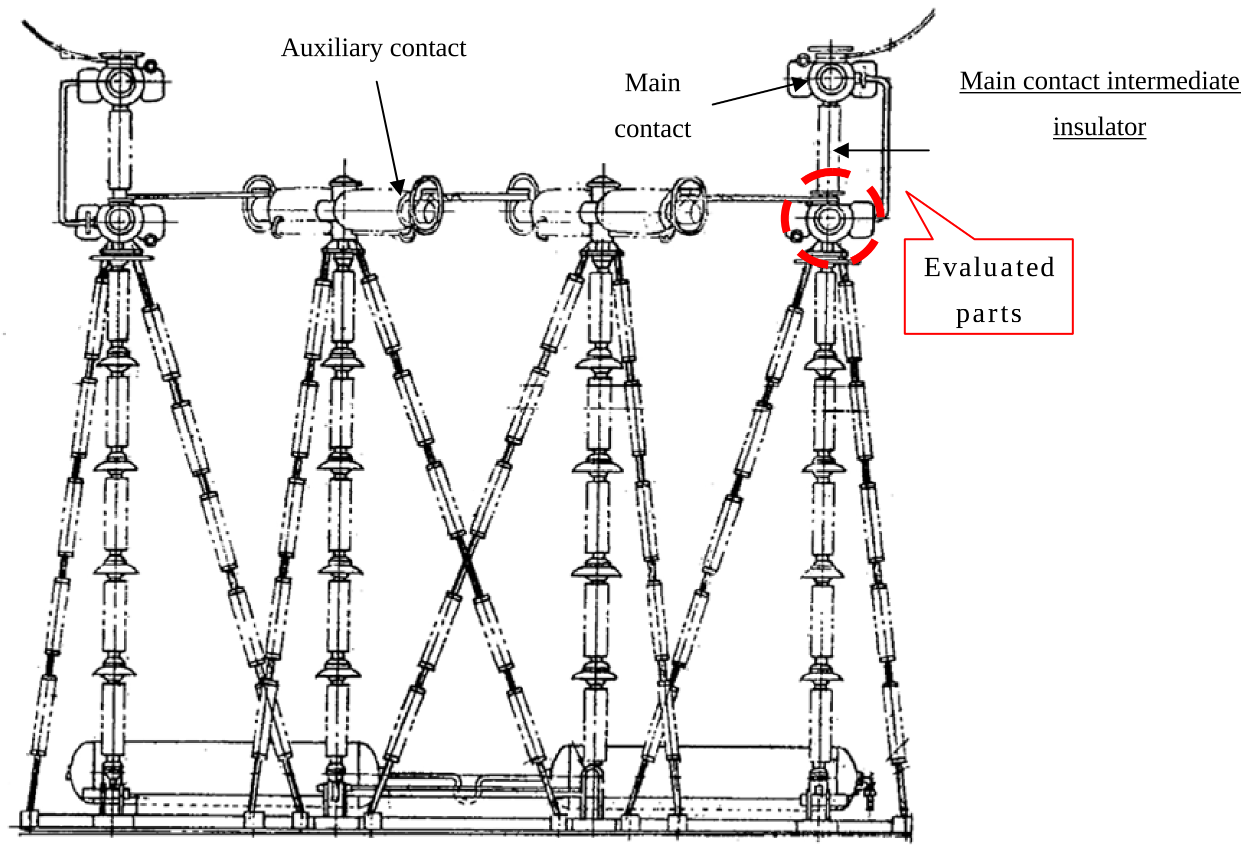

Figure 1: Evaluated parts of 500kV ACB (air) per JEAG5003

Table 4: The evaluation result of transformers at our Nuclear Power Station

Power Station	Unit	Name of transformers	Voltage	Safety ratio	Part
Kashiwazaki Kariwa Nuclear Power Station	1～7	HV Start-up Transformer #1	500/66kV	5.00	Fixed base
		HV Start-up Transformer #2	500/66kV	5.62	Fixed base
		HV Start-up Transformer #3	500/66kV	5.62	Fixed base
		Auxiliary Transformer	154/66kV	3.90	Fixed base
		LV Start-up Transformer Unit 1(A)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 1(B)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 3(A)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 3(B)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 5(A)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 5(B)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 6(A)	66/6.9kV	3.40	Fixed base
		LV Start-up Transformer Unit 6(B)	66/6.9kV	3.40	Fixed base
Fukushima Daini Nuclear Power Station	1～4	HV Start-up Transformer	500/66kV	1.06	Fixed base
		LV Start-up Transformer Unit 1(A)	66/6.9kV	1.65	Fixed base
		LV Start-up Transformer Unit 1(B)	66/6.9kV	1.65	Fixed base
		LV Start-up Transformer Unit 3(A)	66/6.9kV	2.00	Fixed base
		LV Start-up Transformer Unit 3(B)	66/6.9kV	2.00	Fixed base

※This table indicate parts with lowest safety ratio

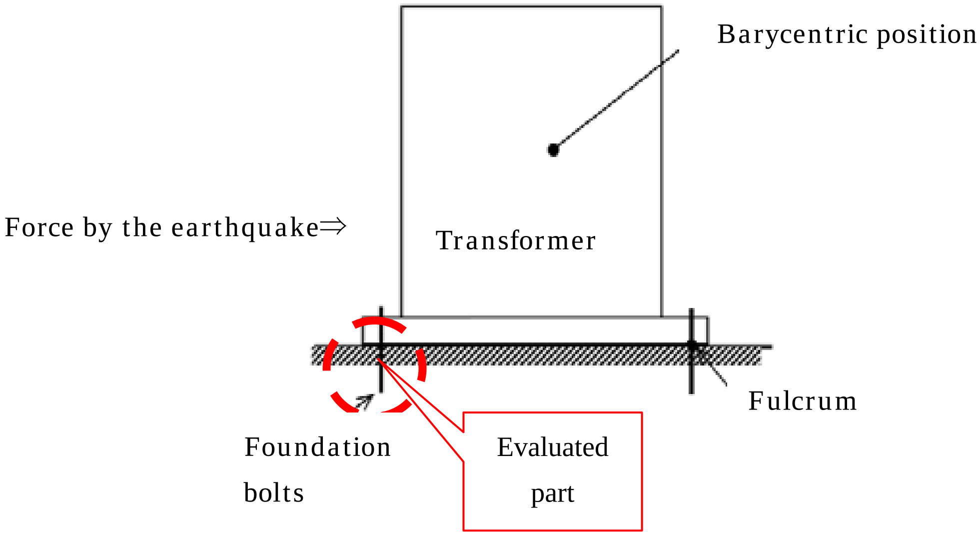

Table 2: Evaluation of transformers

As for switchyard facilities, given that the acceleration amplification factor of 6.1 per chapter 5 (1) of this report, covers almost all of past earthquake data, as long as the safety ratio is at and above 1.3, the risk of the occurrence of collapse or damage that would result in loss of function is regarded as low. As to transformers, since the transformer's natural frequency is relatively high (>15Hz) and away from the peak of acceleration of the earthquake observation result, as long as the safety ratio is at and above 1.0, the risk of the occurrence of collapse or damage that would result in loss of function is regarded as low.

7. Future countermeasures

In this report, we evaluated switchyard facilities and transformers per JAG5003-2010.

As to damages to the Circuit Breakers to Units 1 & 2, Fukushima Daiichi Nuclear Power Station, as there several factor not yet confirmed e.g. response spectrum and failure mode, we plan to evaluate the cause of damages by anti-earthquake analysis as set out in table 5.

Based on the earthquake seismic waveform and the result of analysis, we will implement necessary evaluation. As a result of the evaluation, if there are facilities that require enhancements, we will plan and implement countermeasures.

Table 5: future schedule for evaluation

Item	Jun	Jul	Aug	Sep	Oct	Nov	Dec
① Assume the ground motion at switchyards	━━	━━	━━				
② Prepare the analytical model	━━	━━	━━				
③ Anti-earthquake analysis				━━	━━	━━	
④ Evaluate the cause of damages							━━

① Assume the ground motion at Fukushima Daiichi Nuclear Power Station

As there is no available earthquake observation data at UHV Switchyards for Units 1 & 2, we assume the ground motion from observation records at neighboring observation points. We set indicate the location of observation points at Fukushima Daiichi Nuclear Power Station in figure 3.

The nearest free base observation point to UHV Switchyards for Units 1 & 2 is the earthquake observation room (south point) from records at this point, we assume the ground motion at UHV Switchyards for Units 1 & 2.

②Preparation of the analytical model for switchyard facilities

We construct the analytical model the simulates the structure of the switchyard facilities. This is made of several concentrated mass and springs.

③Anti-earthquake analysis

We use the ground motion assumed by ① as the input data for the analytical model constructed by ② to conduct the anti-earthquake analysis. With this analysis, we calculate stress at each part of equipments.

④Evaluate the cause of damages

We evaluate the cause of damages by (i) comparing the stress to each part per ③ and the design strength of equipments and (ii) the actual damages. We also compare the result of anti-earthquake analysis and the evaluation per JEAG5003.

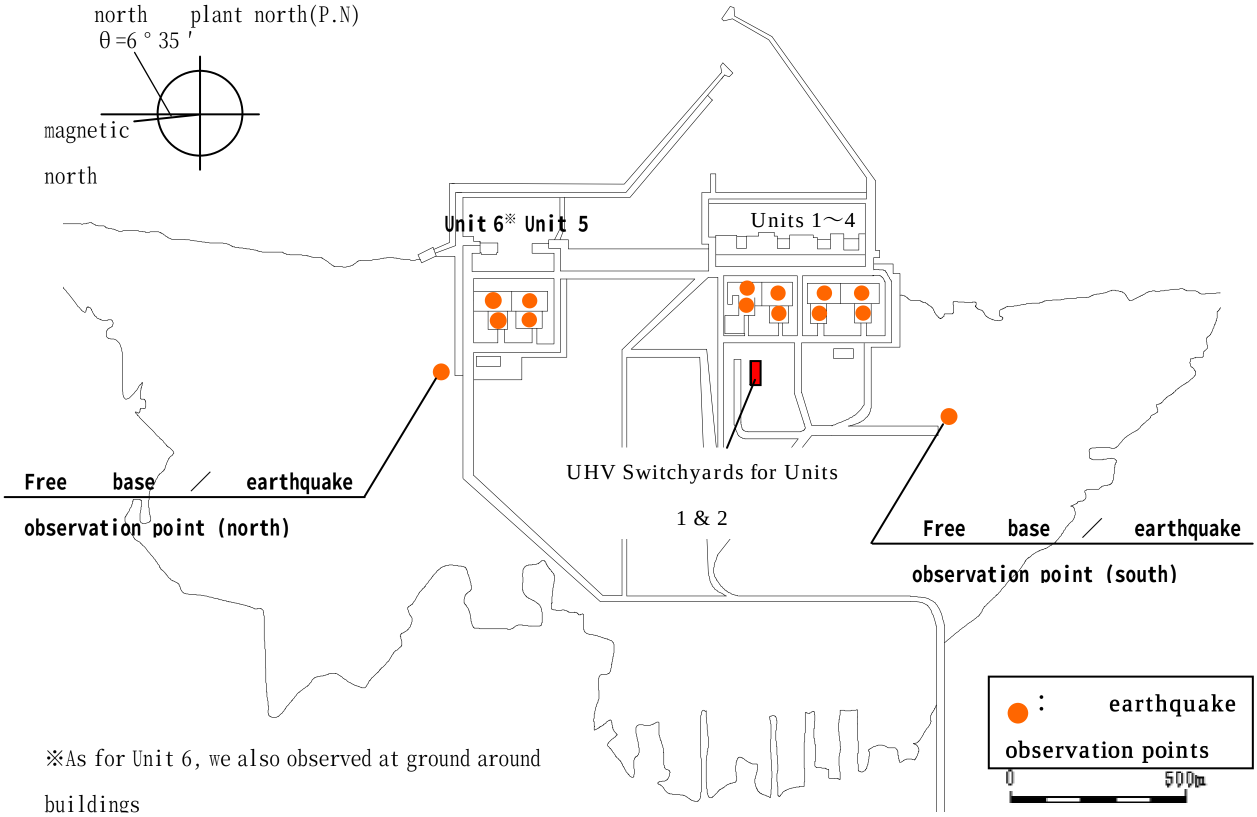

Figure 3: The location of earthquake observation points at Fukushima Daiichi Nuclear Power Station