Plant Data of Fukushima Daiichi Nuclear Power Station at the time of the
Tohoku-Chihou-Taiheiyou-Oki Earthquake

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Tokyo Electric Power Company

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1. Description of data

Fukushima Daiichi Nuclear Power Station was hit by the Tohoku-Chihou-Taiheiyou-Oki Earthquake occurred at 14:46 on March 11th, 2011, and the following massive tsunami, and the plant facilities got severely damaged. While plant data at around the time of the earthquake remained at the site including the main control room of each unit, we had no choice but to focus on the work for stabilization of the plants. Since it was difficult to take the printed data directly to the uncontaminated area due to the high level air dose around the plants including the main control rooms and the prints themselves were contaminated, we could not computerize the data by staying in the main control rooms for long hours. However, as the situation gradually improved, we collected and organized as much plant data as possible in accordance with the instructions from the national government. Data collected and organized are as below.

(1) Charts

Recording papers widely used to record various data of the plants. Plant data are recorded in roll paper with color ink.

(2) Data of abnormal events including alarm records

A kind of data output from process computers, including the times of abnormal events and operation logs of the plant systems. They are basically printed out and kept as printed records.

(3) Operation logs

Operation records, data recorded by operators in the main control rooms and daybooks with handover messages for operators of the next shift.

(4) Data of process computers

Process computers also store data indicating plants' behavior. Their functions are similar to the transient recorders described below.

(5) Data of transient recorders

Triggered its operation by the occurrence of abnormal events, a transient recorder records numerical data on plant's behavior for a few minutes prior to and 30 minutes after the event.

The amount of data above varies, depending on the plant situation and the type of the computer. For example, Unit 4 was in the regular inspection and all of the fuels were taken out to the spent fuel pool in order to replace its shroud. Since the process computer was being replaced at the same time, related data does not exist. Also, since the transient recorder of Unit 6 was not in operation due to the unit's regular inspection, transient record of Unit 6 does not exist. Data organized in this report are described in Table-1.

While most of major data were collected and organized in this report, please note that there still can be some data unrecorded due to the damage of the detectors caused by tsunami. As further facts are getting revealed by detailed analyses of other parameters and reliable

evidences from persons involved, it is expected that additional information such as operation records of equipments will be known in the future. In such a case, we will report them accordingly.

2. References
    (1) Unit 2, Fukushima Daiichi Nuclear Power Station
         Restoration of alarm records
    (2) Unit 3, Fukushima Daiichi Nuclear Power Station
         Adjustment of the recorded times of the transient recorders

Table-1

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Note
Plant Status	In operation	In operation	In operation	In regular inspection (all fuels removed)	In regular inspection (RPV in pressure test)	In regular inspection (RPV shut down)	Note
Charts	While the charts have some records after the earthquake, data after tsunami are quite limited because power and signals of indicators were lost due to tsunami. Some indicators are in operation again after the restoration of the power, but we collected and attached plant parameters with consideration of data continuity.						
Process Computers — Data including alarm records	Data until 15:00, March 11 collected.		Data until 19:00, March 11 collected.	Process Computers are being replaced.	Regular recording function does not work due to the regular inspection.	Regular recording function does not work due to the regular inspection.	BOP (Operation data)
	Data printed with Typer -Core performance: Until 14:00, March 11 -Position of control rods: Until 15:00, March 11		Data printed with Typer -Core performance: Until 19:00, March 11 -Position of control rods: Until 18:00, March 11				Calculation of core performance, position of control rods etc.
	Data until approx. 10 minutes after scram printed with Typer	Data until approx. 2 minutes after scram printed with Typer. Data until 15:50, March 11 have been restored by hard drives collected.	Data until approx. 18:00, March 11 printed with Typer		Data until approx. 2 minutes after earthquake printed with Typer. Data until 16:18, March 12 have been restored by hard drives collected.	Data until approx. 15:40, March 11 printed with Typer	Alarm records
Process Computers — Data of Process Computers (Operation data)	Difficult to obtain	Hard drives of data storage servers collected.	Difficult to obtain		Hard drives of data storage servers collected.	Difficult to obtain	
Process Computers — Supplemental Description on Functions of Process Computers	No reproduction function of alarm records	Reproduction function of alarm records exists. To collect undiscovered data, power will be needed.	No reproduction function of alarm records		Reproduction function of alarm records exists. Power needed.	No reproduction function of alarm records	
	Unusually powered by AC. When AC power lost, power source switched to batteries. (A part of equipments of Unit 2 powered by regular source.)				Unusually powered by AC. When AC power lost, power source switched to batteries. (Batteries of Unit 5 are exclusive to computers.)		
Operation Logs	Operation logs of March 11 are collected.						

Daybooks with handovers for next operators	There are 2 kinds of daybooks, being for chief operators and for members. Both daybooks on the 2nd shift of March 10 and the 1st shift of March 11 are collected. Actions taken on March 11 after earthquake were described on the white boards in the main control rooms, and transcribed to the daybooks thereafter. Memorandums also collected.	There are 2 kinds of daybooks, being for chief operators and for members. Both daybooks on the 2nd shift of March 10 and the 1st shift of March 11 are collected. We also collected memorandums about operations, which were organized in Main Anti-Earthquake Building.	There are 2 kinds of daybooks, being for chief operators and for members. Both daybooks on the 2nd shift of March 10 and the 1st shift of March 11 are collected.		
Transient Recorders	Data collected from hard drives removed.	Difficult to remove hard drives. Data collected by repowering.	Transient Recorders are being replaced.	Data collected from hard drives removed.	Event recording function does not work due to the regular inspection.
	Unusually powered by AC. When AC power lost, power source switched to batteries.			Unusually powered by AC. When AC power lost, power source switched to batteries. (Batteries of Unit 5 are exclusive to computers.)	

Unit 2, Fukushima Daiichi Nuclear Power Station
Restoration of alarm records

1. Introduction

    It is recognized that the alarm equipment (function of output alarm records to Alarm Typer) of Unit 2, Fukushima Daiichi Nuclear Power Station produced records for approximately 2 minutes immediately after the scram, but stopped thereafter for some reasons. We restored alarm records based on the data stored in hard drives.

2. Overview of the functions of alarm equipments

    The alarm equipments have functions to collect information about plant status from process computers and produce alarm records to Alarm Typer.
    Items of information produced to Alarm Typer are as below.

        Status changes of Digital Input Points (changes of contact points)
        Changes of the position of control rods
        Monitoring Alarm (excess of the limits/restoration)
        Operation records (data insertion / alarm exclusion / scan exclusion)
        Transferred results of outputs from computers
        Time and messages

    The restoration of alarm records this time was conducted as to   and   , based on the record of plant process data produced by the process computer of Unit 2. The ways to produce   and   are as below.

    a. Way to produce the status changes of Digital Input Points
        In the case of occurrence of change of contact point the time and the situation are output to Alarm Typer.
    b. Way to produce Monitoring Alarm (excess of the limits/restoration)
        In the case that the monitored Analogue Input Point exceeds the alarm limit or deviates from the designated range or that indicator trouble occurs, the time and the situation are output to Alarm Typer.

3. Methodology for the restoration of alarm records
    Among records, 1171 Analogue Input Points and 503 Digital Input Points of the plant process data were used for the restoration of alarm records. Position data related to the movement of control rods were not used.
    In the restoration, automatic process methods searching for record data (excel files) were

adopted as below.

(1) Digital Input Point

Search for the time of occurrence of change in status of the target input point and output the time, PID and the value before and after the change

(2) Analogue Input Point

Search for the time of occurrence of change in quality information of the target input point and output the time, PID and the value before and after the change

End

In the case of Digital Input Point

First window:

	8	9	10	11	12	13	14	15	16	17	18	19
1 ポイントID	D703		D706		D707		D708		D709		D710	
2 ポイント詳細	RCIC 注入		ADS A 注		ADS B 注		SGTS A		SGTS B		SRNM 計	
3 ポイント単位	OFF/ON		OFF/ON		OFF/ON		OFF/ON		OFF/ON		正常/高高	
631 2011/3/11 14:50:27	OFF	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
632 2011/3/11 14:50:28	OFF	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
633 2011/3/11 14:50:29	OFF	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
634 2011/3/11 14:50:30	OFF	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
635 2011/3/11 14:50:31	OFF	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
636 2011/3/11 14:50:32	OFF	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
637 2011/3/11 14:50:33	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
638 2011/3/11 14:50:34	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
639 2011/3/11 14:50:35	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
640 2011/3/11 14:50:36	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
641 2011/3/11 14:50:37	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
642 2011/3/11 14:50:38	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
643 2011/3/11 14:50:39	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
644 2011/3/11 14:50:40	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
645 2011/3/11 14:50:41	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
646 2011/3/11 14:50:42	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
647 2011/3/11 14:50:43	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
648 2011/3/11 14:50:44	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
649 2011/3/11 14:50:45	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
650 2011/3/11 14:50:46	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
651 2011/3/11 14:50:47	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
652 2011/3/11 14:50:48	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
653 2011/3/11 14:50:49	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
654 2011/3/11 14:50:50	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
655 2011/3/11 14:50:51	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報
656 2011/3/11 14:50:52	ON	正常	OFF	正常	OFF	正常	ON	正常	OFF	正常	高高	警報

Second window:

	68	69	70	71	72	73	74	75	76	77	78
2				2011/3/11 14:50:33	D703	RCIC 注入弁 開	OFF	ON	正常	正常	
3				2011/3/11 15:25:34	D703	RCIC 注入弁 開	ON	OFF	正常	正常	
4				2011/3/11 15:39:42	D703	RCIC 注入弁 開	OFF	ON	正常	正常	
5				2011/3/11 14:47:43	D708	SGTS A 起動信号	OFF	ON	正常	正常	
6				2011/3/11 14:48:14	D708	SGTS A 起動信号	ON	OFF	正常	正常	
7				2011/3/11 14:48:22	D708	SGTS A 起動信号	OFF	ON	正常	正常	
8				2011/3/11 15:37:39	D708	SGTS A 起動信号	ON	OFF	正常	正常	
9				2011/3/11 15:37:55	D709	SGTS B 起動信号	OFF	ON	正常	正常	
10				2011/3/11 15:40:36	D709	SGTS B 起動信号	ON	OFF	正常	正常	
11				2011/3/11 14:47:50	D710	SRNM 計数率 高高 CH 正常	高高	正常	警報	正常	
12				2011/3/11 14:55:19	D710	SRNM 計数率 高高 CH 高高	正常	警報	正常		
13				2011/3/11 14:47:50	D711	SRNM 計数率 高高 CH 正常	高高	正常	警報	正常	
14				2011/3/11 14:55:02	D711	SRNM 計数率 高高 CH 高高	正常	警報	正常		
15				2011/3/11 14:47:50	D712	SRNM 計数率 高高 CH 正常	高高	正常	警報		
16				2011/3/11 14:54:41	D712	SRNM 計数率 高高 CH 高高	正常	警報	正常		
17				2011/3/11 14:47:50	D713	SRNM 計数率 高高 CH 正常	高高	正常	警報		
18				2011/3/11 14:55:06	D713	SRNM 計数率 高高 CH 高高	正常	警報	正常		
19				2011/3/11 14:47:50	D714	SRNM 計数率 高高 CH 正常	高高	正常	警報		
20				2011/3/11 14:55:06	D714	SRNM 計数率 高高 CH 高高	正常	警報	正常		
21				2011/3/11 14:47:50	D715	SRNM 計数率 高高 CH 正常	高高	正常	警報		
22				2011/3/11 14:54:35	D715	SRNM 計数率 高高 CH 高高	正常	警報	正常		
23				2011/3/11 14:47:50	D716	SRNM 計数率 高高 CH 正常	高高	正常	警報		
24				2011/3/11 14:54:28	D716	SRNM 計数率 高高 CH 高高	正常	警報	正常		
25				2011/3/11 14:47:50	D717	SRNM 計数率 高高 CH 正常	高高	正常	警報		
26				2011/3/11 14:53:43	D717	SRNM 計数率 高高 CH 高高	正常	警報	正常		
27				2011/3/11 14:48:03	D725	SRNM ペリオド 短短 CH 正常	短短	正常	警報		
28				2011/3/11 14:48:05	D725	SRNM ペリオド 短短 CH 短短	正常	警報	正常		
29				2011/3/11 14:48:10	D725	SRNM ペリオド 短短 CH 正常	短短	正常	警報		

In the case of Analogue Input Point

Unit 3, Fukushima Daiichi Nuclear Power Station
Adjustment of the recorded times of the transient recorders

1   Outline of the recording by the transient recorder of Unit 3

The transient recorder installed at Unit 3 starts recording data in the case of an event that makes substantial change in preset plant parameters. At the time of the Tohoku-Chihou-Taiheiyou-Oki Earthquake on March 11, the transient recorder started recording at 14:46, 14:47, 14:59, 15:09, 15:19 and 15:29 and recorded data for 5 minutes before and after the each starting time (10 minutes in total for each). It should be noted that every parameter triggered the recording was on the vibration of the upper part of the recirculating pump except for the reactor scram at 14:47.

Since these data do not have the recorded times, time-series data is necessary to be developed through the restoration of fragmented information based on the times of the trigger events. In the process of the restoration, we compared the data of the transient recorder with other records (charts, Alarm Typer etc.) and made adjustments to a part of the time data, as we found inconsistency in a part of the data.

2   Discontinuity of the recorded data

Figure 1 shows the data of the water level of the reactor (narrow band).
This shows that the water level rapidly increased at around 14:59 (signed with arrow) and went over the scale limit (1,500 mm) only in 0.1 second from approx. 1,300 mm. Similar fluctuation was recorded in broad band data, but the fluctuation range was approx. 400 mm, which was inconsistent. On the other hand, Alarm Typer recorded fluctuation of the water level around 1,000 mm at around 15:00.
Taking into account those inconsistencies, we examined other data than water level and found several discontinuities in parameters. Examples are;
   - D/G (A) Current   72A   146A
   - Rotation Velocity of Turbine   263 rpm   5 rpm
Consequently, we determined that the recorded data this time has discontinuity at around 14:59.
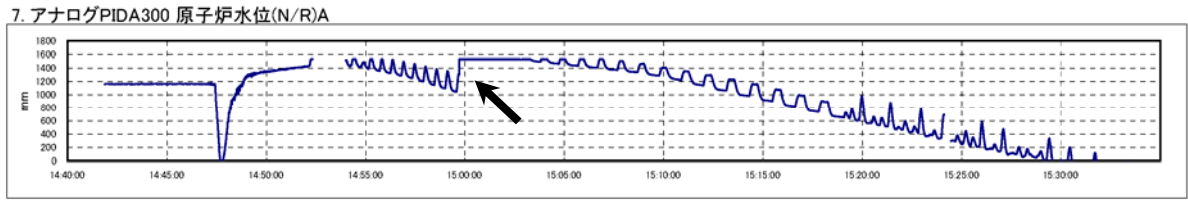
7. アナログPIDA300 原子炉水位(N/R)A

Figure 1: Data of the water level of the reactor (narrow band)

3 Consistency with other records

Since inconsistencies have been found among the recorded times, as described in section 2, we conducted estimation of correct times through comparing with other records (charts, Alarm Typer etc.).

3.1 Comparison with the water level in the reactor

Figure 2 is the chart of the water level in the reactor (narrow band).

Figure 2 tells that the water level of the reactor went over the scale limit at around 15:30 and went blow the limit at around 16:00. These can be confirmed in the Alarm Typer records indicating that the water level went over the upper scale limit at 15:25 and went below the lower scale limit at 15:59. Based on the information above, data recorded by the transient recorder from 15:00 to 15:30 can be estimated as data from 15:30 to around 16:00 in actual.

And, Alarm Typer has records that the water level went in the reactor over the scale limit and came back 4 times at around 15:35, and these movements are in line with the transient recorder's data at around 15:05. This concurrence also supports the estimation that the transient recorder recorded data 30 minutes late.
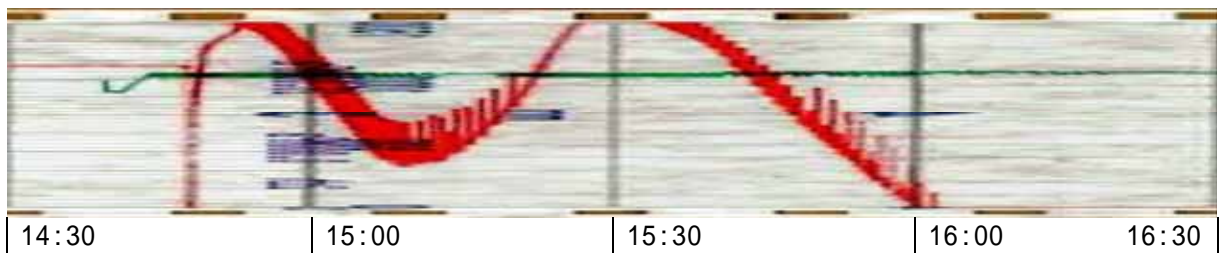

| 14:30 | 15:00 | 15:30 | 16:00 | 16:30 |

Figure 2: Water level in the reactor (narrow band) and Chart (in red)

Note: Because of the differences of the feeding speed and the up/down direction of paper, the figure is enlarged and reversed.

3.2 Comparison with the time when the emergency diesel generator (D/G) stopped (Alarm Typer)

Figure 3 shows the voltage of the emergency diesel generator (A), which was recorded by the transient recorder. Based on this figure, it seems that D/G stopped at approx. 15:08, but Alarm Typer recorded D/G's trip at 15:38. Here is approx. 30 minutes gap with the data of the transient recorder again.

21. AnaloguePIDA754, Voltage of D/G 3A R-T

Figure 3: Voltage of D/G 3A

3.3 Comparison with the movement of Safety Relief Valve (Alarm Typer)

Figure 4 shows the movements of Safety Relief Valve, indicating that Safety Relief Valve had not moved since around 15:18. However, compared with the record that Alarm Typer printed the movements of Safety Relief Valve until 15:39, here is approx. 30 minutes gap with the data of the transient recorder again.

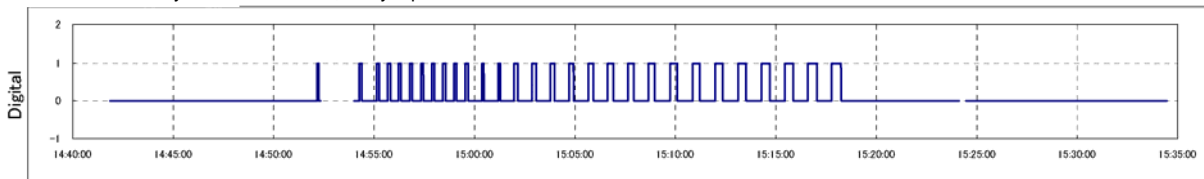21. D728 Safety Relief Valve C, fully opened

Figure 4: Movements of Safety Relief Valve

4 Adjustment of the recorded times

As described above, the duration of the interruption of the data is estimated to be approx. 30 minutes, based on the judgment that there is discontinuity of data at around 14:59:43 on March 11. Therefore, we made adjustment to the time, approx. 30 minutes, after 14:59:43 on March 11.

End