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Efforts to Tsunami Prediction that Utilize the Offshore Tsunami Data in Nuclear Power Stations

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ABSTRACT

In the wake of tsunami caused by the 2011 off the Pacific Coast of Tohoku Earthquake (the 3.11 tsunami), efforts to prevent and reduce tsunami damage have increasingly been important. For safety improvement of nuclear power stations, early prediction and detection of the height and arrival time of tsunami can be useful information in making prompt initial responses and recovery activities.

As part of a safety improvement of nuclear power stations, we have been actively enhancing tsunami prediction and tsunami monitoring systems in addition to facility measures against tsunami.

In this paper, as part of these efforts, we report on the development of a tsunami prediction method utilizing the offshore tsunami data (GPS wave gauge data that has been observed by the Ministry of Land, Infrastructure, Transport and Tourism) and the introduction of a tsunami monitoring system.

Concerning this tsunami prediction method, we conducted approximately 9500 simulations in which we assumed wave sources in the front of our nuclear power stations, the Pacific Ocean off the coast, and created a database, enabling rapid tsunami prediction at nuclear power stations. This system also contributes to the safety improvement of our nuclear power stations because we can obtain detailed information on tsunami in addition to tsunami forecasts by the Japan Meteorological Agency.

1. Introduction

Onagawa and Higashidori nuclear power stations of Tohoku Electric Power Co., Inc. are located in the Pacific coastal region of the Tohoku district. On March 11, 2011, the massive tsunami of approximately 13 m attacked the Onagawa Nuclear Power Station (Onagawa). All units of Onagawa secured cold shutdown without causing a major accident. However, in the wake of this tsunami, the importance of efforts to prevent and reduce tsunami damage has been increasing.

In parallel with the implementation of facility measures against tsunami, such as upgrading the seawall, for further safety improvement in addition to conventional measures, we have been proactively promoting the enhancement of tsunami prediction and tsunami monitoring systems.

Specifically, we have established a tsunami prediction method utilizing the offshore tsunami data (GPS wave gauge data that has been observed in real-time the offshore situation immediately after the occurrence of tsunami by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT)) at Onagawa and Higashidori nuclear power stations.

2. Offshore Tsunami Data used for Prediction

For tsunami prediction, early detection and prediction accuracy are vital. We tried to predict tsunami height and arrival time at power stations by capturing sea level changes at the position of GPS wave gauges installed the offshore of stations. Figure 1 shows an image of tsunami prediction using the GPS wave gauge data.

GPS wave gauges have been installed by MLIT to observe offshore wave information necessary for port maintenance all over the country, including off the Pacific coast of the Tohoku region, since March 2007.

In relation to the tsunami prediction at Onagawa, we evaluated the data of the offshore northern part of Miyagi Prefecture (off Hirota Bay) and the offshore middle part (off Mt. Kinkazan). Concerning Higashidori, we evaluated the data of the offshore east part of Aomori Prefecture (off Hachinohe). Figure 2 shows the location of power stations to predict and GPS wave gauges.

We are receiving these data based on the agreement between MLIT and the Federation of Electric Power Companies of Japan with an aim to make effective use of offshore wave observation data and secure the safety of power facilities on the coast.

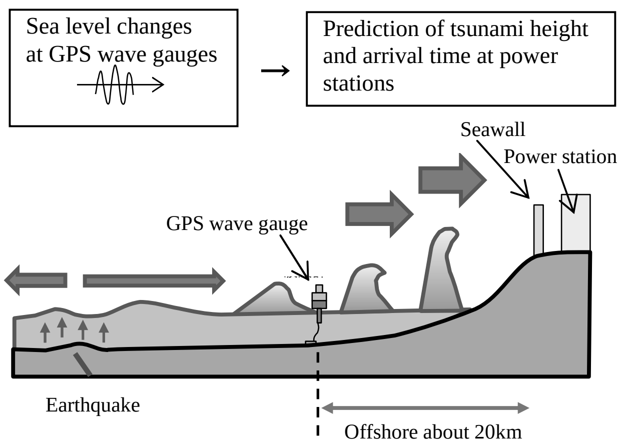

Figure 1. Image of tsunami prediction utilizing GPS wave gauge data

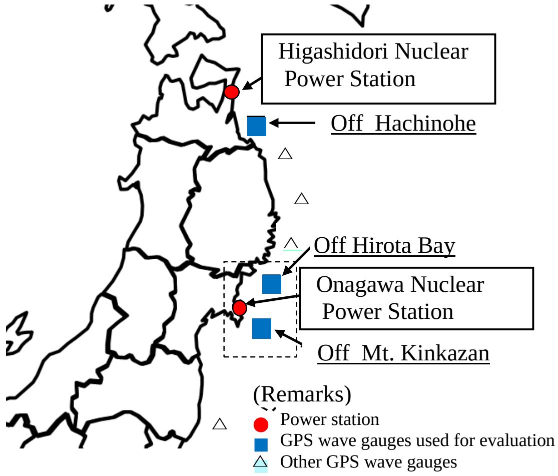

Figure 2. Location of power stations and GPS wave gauges

3. Tsunami Prediction Method

We created a database of correlation between GPS positions and the tsunami height and arrival time of tsunami at our power stations to promptly predict after receiving GPS wave gauge data.

First, based on the past research, we set up a tsunami fault model that is expected to make an impact on the power stations, and we conducted 9500 simulations (Fig. 3 and 4).

Next, we calculated the height of the tsunami at the position of the GPS wave gauge and power stations, which is arranged as a coefficient (conversion factor) to convert the tsunami height at GPS positions to the tsunami height at the position of power stations (Fig. 5).

Similarly, we arranged the relationship between tsunami height at GPS positions and tsunami arrival time difference (between power stations and GPS positions) (Fig. 6).

In this way, utilizing GPS wave gauge data, we have established a database that can predict the minimum and maximum values of tsunami height reaching power stations, and the fastest and latest value of tsunami arrival time.

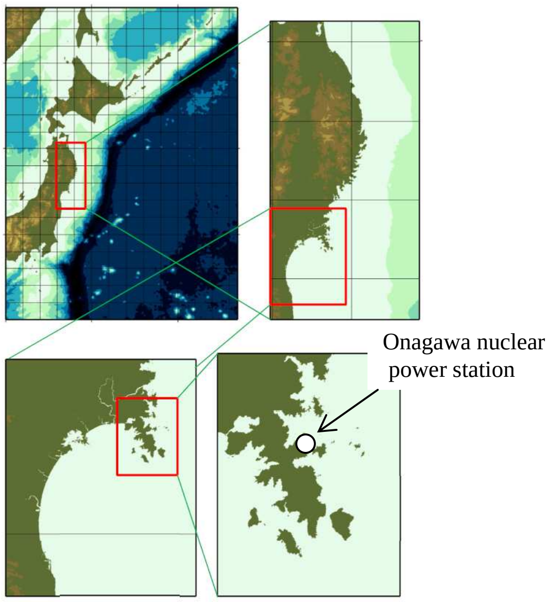

Figure 3. Calculating area
(Onagawa NPS)

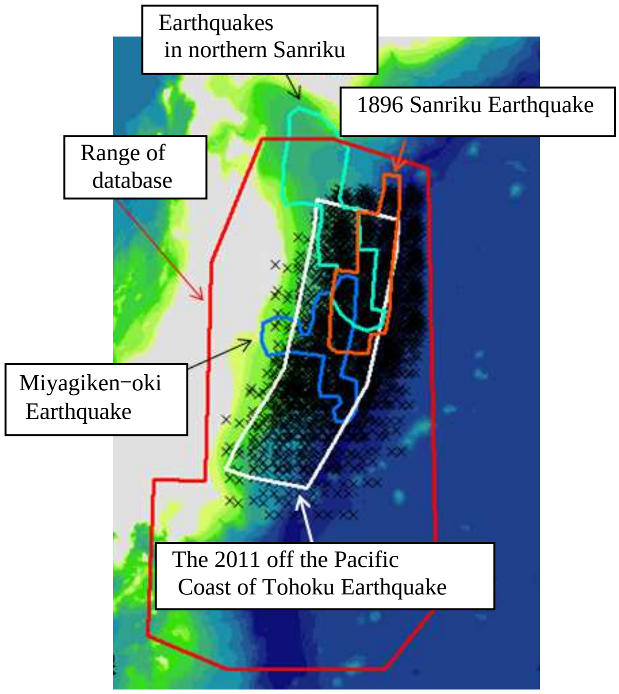

Figure 4. Outline of tsunami fault model

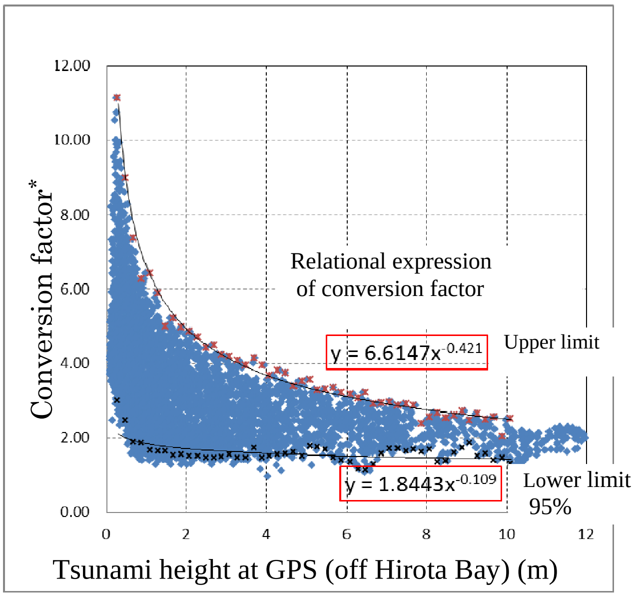

Figure 5. Relationship between conversion factor and tsunami height at GPS positions
(*: Tsunami height at power station / at GPS position)

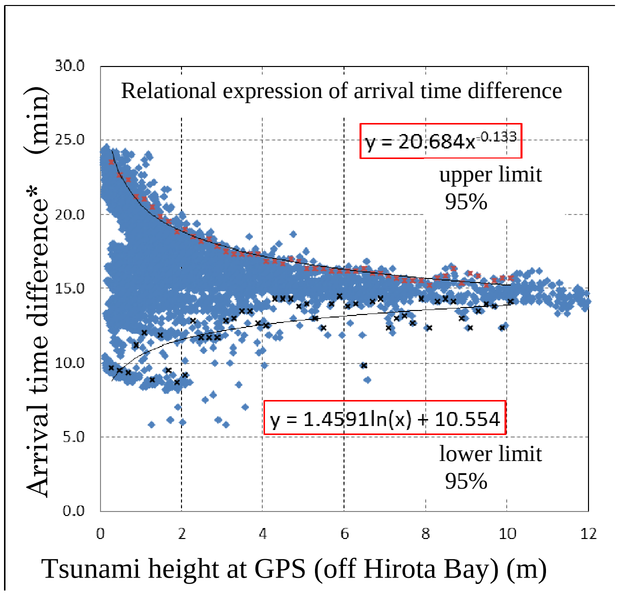

Figure 6. Relationship between arrival time difference and tsunami height at GPS positions
(*: Tsunami arrival time at power station – at GPS position)

4. Validation of Tsunami Prediction Database

We verified the database used for tsunami prediction by comparing it with the observation results of the tsunami caused by the 3.11 tsunami and the simulation results of Miyagiken-oki earthquake and others.

In 3.11 tsunami, tsunami height of 5.4 m was measured off the northern part of Miyagi Prefecture (off Hirota Bay) .When this is applied to this database, the minimum value and the maximum value of the height of the tsunami at Onagawa are approximately 8 m to 19 m. In reality, the maximum tsunami height of about 13 m was observed at Onagawa. We confirmed that the actual tsunami height is almost the median of the predicted value (Fig. 7).

In addition, we confirmed the validity of the tsunami prediction using this database regarding the arrival time difference between the power station and GPS positions. The arrival time difference actually observed was 15 minutes, whereas the fastest and the latest value of the predicted value are 13 to 16 minutes (Fig. 8).

Furthermore, we calculated conversion factor (coefficient to convert the tsunami height at GPS position to it at the power station) and arrival time difference between the power station and GPS positions for major historical earthquakes which affected Onagawa. As a result, except for cases where tsunami height at the power station is low, because past tsunami is almost included in the range of the upper and lower limits of this database prediction formula, we have confirmed that the fault parameters when creating the database were set appropriately (Fig. 7, Fig. 8).

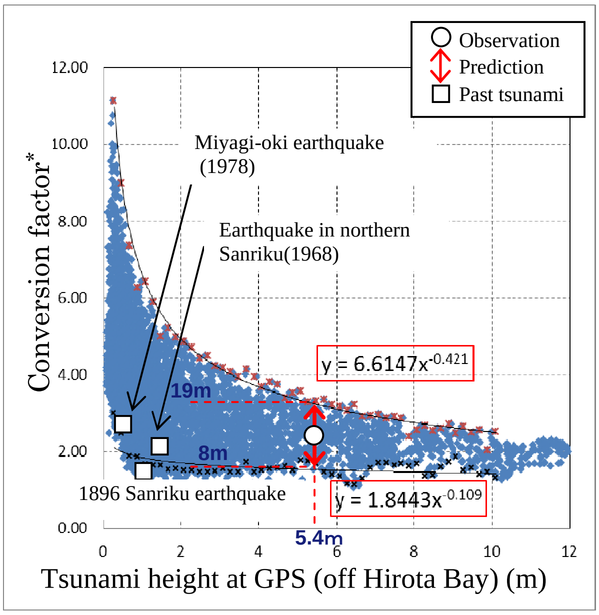

Figure 7. Validity of tsunami prediction

(Conversion factor)

(*: Tsunami height at power station / at GPS position)

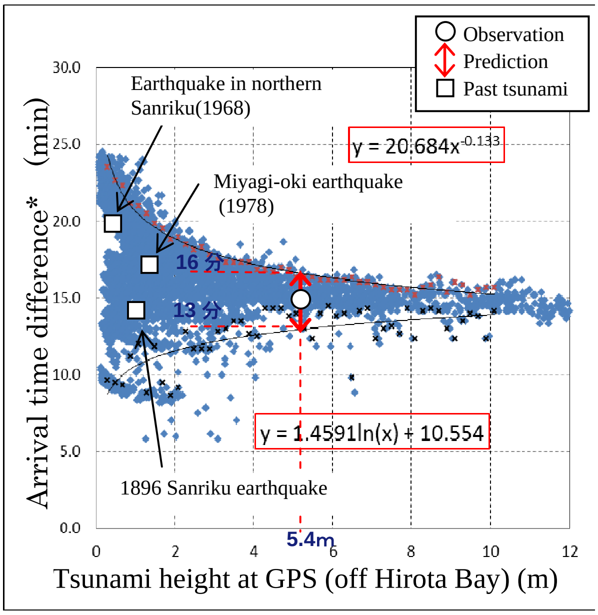

Figure 8. Validity of tsunami prediction

(Arrival time difference)

(*: Tsunami arrival time at power station – at GPS position)

5. Tsunami Monitoring System

Based on the above prediction method, we built a tsunami monitoring system and started the operation of it at Onagawa, Higashidori and the Head Office in March 2014. This system contributes to the safety improvement of our nuclear power stations because we can gain detailed information on tsunami in addition to tsunami predictions by the Meteorological Agency. We also attach importance to usability in times of disasters, so this system is equipped with uninterruptible power supply (UPS) and an anti-seismic device.

Prediction results are immediately displayed when the extreme value of the tide level deviation is observed by the GPS wave gauge, and predictions start when the following conditions are satisfied.

(1) When a tsunami forecast is announced by the Meteorological Agency in a tsunami forecast zone with our power stations and significant tide level deviation is detected by the GPS wave gauge used for tsunami prediction.

(2) Even when a tsunami forecast is not announced, significant tide level deviation larger than (1) is detected by the GPS wave gauge used for tsunami prediction.

At the time of the start of tsunami prediction and display of prediction results, the rotating warning light will ring and light up so that we will not overlook the information.

In the system, in addition to prediction of tsunami height and arrival time, changes over time of the tide level deviation measured by the GPS wave gauge is displayed, which enables to continuously monitor offshore wave situation (Photo 1 and Fig. 9).

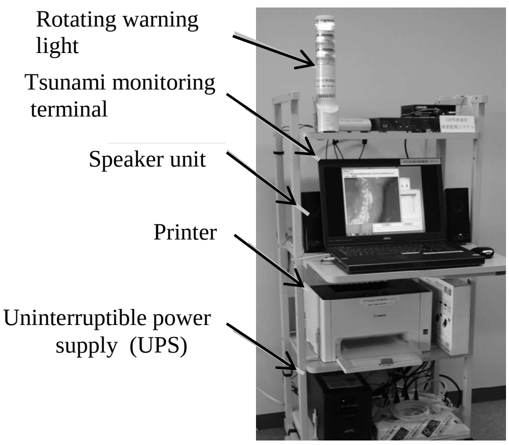

Photo1. Tsunami monitoring system

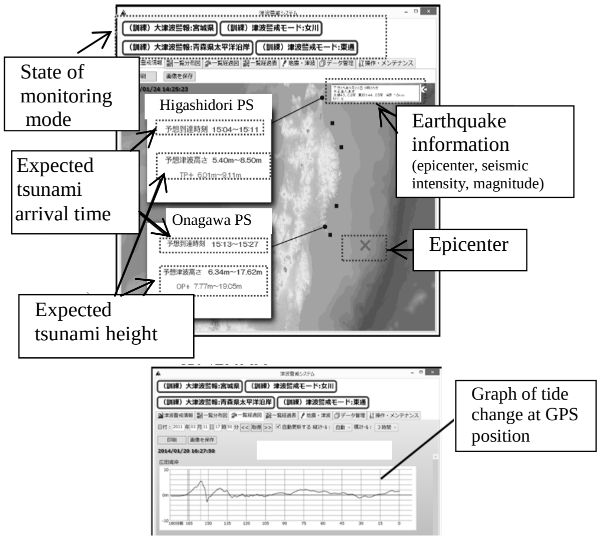

Figure 9. Screen display of tsunami monitoring system

6. Conclusion

We made it possible to quickly predict tsunami height and arrival time at our power stations through establishing the system mentioned above. In parallel to the reinforcement of facility measures (tangible safety measures), comprehensive intangible safety measures, such as the enhancement of tsunami prediction and others, are essential to further improve the safety of nuclear power plants.

Until now, we have basically referred to the Japan Meteorological Agency's tsunami prediction in establishing an initial response system at the time of a disaster and recovery work after an accident at nuclear power stations. From now on, further safety improvement will be expected thanks to pinpointed tsunami prediction at power stations and diversification of information.

We resolve to make continuous efforts to intensify the accuracy of tsunami prediction and diversify the monitoring system to further enhance the safety of nuclear power plants.

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2) Ikuo ABE, Fumihiko IMAMURA (2009): Influence of Initial Conditions on Local Real-time Tsunami Forecast and its Setting up, Journal of Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol. B2-65, No1, pp336-340