Development and Practical Implementation of Disaster Prevention System with Application of Emergency Earthquake Bulletin

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Japan can be referred to as a major earthquake prone nation, one of the few nations in the world where earthquakes occur. This is due to the continental and oceanic plates that border the coastline of the Pacific Ocean of Japan, as well as several hundred active faults that exist inland, which are the source of earthquakes throughout the entire nation. It would not be an exaggeration to say that as long as people live in Japan, strategies against earthquakes are essential (there is no means to escape earthquakes).

As a matter of fact the manufacturer of semiconductors, Miyagi Oki Electric, incurred damage from a total of three earthquake disasters categorized as having a seismic intensity “5 upper” from 2003 to 2005. Even though no humans lost their lives, fortunately, the company suffered a total loss of approximately three billion yen as a result of the three earthquakes.

Many dangerous special gases and chemicals are handled at semiconductor manufacturing plants. If any of these types of dangerous substances were to leak due to tremors brought about by earthquakes, not only would human loss be anticipated but also fires as well as damage in terms of the destruction or erosion of expensive equipment. Secondary disasters arising from such earthquake tremors are more dangerous than primary disasters directly caused by earthquakes and they have a greater potential for becoming large scale disasters. At Miyagi Oki Electric we have been implementing various strategies for making our plant “the most robust semiconductor manufacturing plant in the world”. Following the second earthquake disaster experienced in 2003 a Disaster Management Committee was established in order to offer “peace of mind” to all relevant persons through assurances for the safety of our employees and by providing a stable supply of products to our customers.

Science is currently unable to stop the occurrence of earthquakes and although forecasting is also almost impossible at the present time, secondary disasters can be prevented from occurring with procedures to secure gases, chemicals and facilities in a safe condition (thereby making it possible to minimize earthquake disasters) before a principal shock (the main shock and S-wave) hits the site, through effective use of the Emergency Earthquake Bulletin[*1].

For this reason Miyagi Oki Electric developed and conducted practical implementation[1] of an earthquake disaster prevention system in collaboration with REIC (Real-time Earthquake Information Consortium).

Effectiveness of Emergency Earthquake Bulletin

In the past the disaster prevention system at Miyagi Oki Electric had been triggered by particular threshold values of S-wave earthquakes (vibration acceleration) for tasks, such as issuing emergency warnings to employees, shutting off various gases, suspending the supply of chemicals and terminating operations for some precision equipment. Since the operation of a system after an S-wave was detected involved operating during a large tremor, however, depending on the scale of the earthquake, there was a potential danger of the system to not operate in a stable manner and procedures implemented once the tremor had been detected may have been too late in some cases.

If the arrival of a large tremor can be forecast, even just tens of seconds before its arrival, it would be possible for a manufacturing plant to implement the safety and disaster reduction procedures cited below:

a. Employees: To ensure safe position and primary escape to safety zones.
b. Various dangerous special gases: To assure implementation of procedures when gases are not shut off once a tremor is detected, due to the fall and destruction of relevant facilities.
c. Facilities and products: To minimize damage to precision equipment and high-speed rotating devices (such as vacuum pumps) by stopping them in advance, as well as implementing damage prevention strategies for our silicon wafer products, while implementing advance procedures for easily damaged parts and materials, such as quartz or SiC (materials used for semiconductor tools for which a high degree of purity, thermal resistance and chemical resistance are required, which are vulnerable to impact).

As for the safety of employees in particular, psychological preparation, arising from the ability to warn them in advance that a tremor will be occurring, leads to the prevention of unforeseen accidents arising from panic and makes it possible to secure their safety through the implementation of pre-determined behavioral standards[2].

Emergency Earthquake Bulletin distributed by Meteorological Agency

Before moving on to a description of the system, a summary of the system is provided using the flow of the Emergency Earthquake Bulletin distributed by the Meteorological Agency, with the model of an earthquake that is predicted to occur with a certainty of 99% off the coast of Miyagi Prefecture within a 30 year period.

*1) The Emergency Earthquake Bulletin is earthquake information obtained from a network of seismic stations, transmitted immediately to reduce damage caused to the social economy.

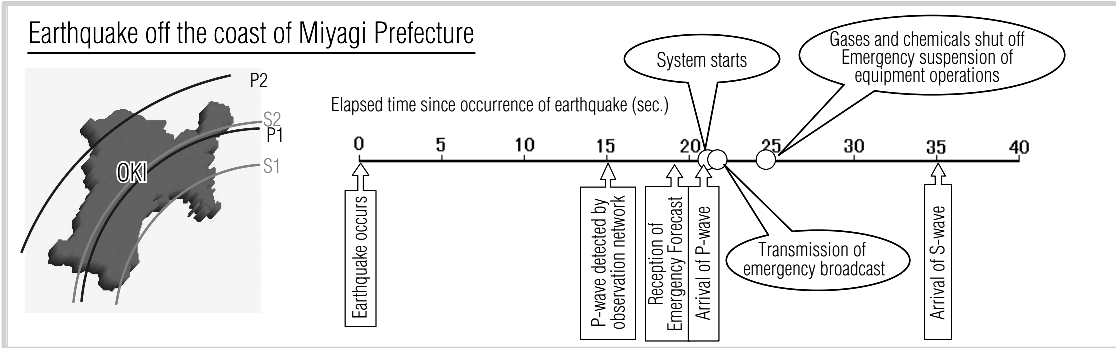

Fig. 1 Propagation time chart for seismic waves

The propagation of seismic waves when an anticipated earthquake occurs off the coast of Miyagi Prefecture, along with the transmission time chart for the Emergency Earthquake Bulletin distributed by the Meteorological Agency, are shown in **Fig. 1**. Once an earthquake occurs the first point of observation (points installed at 25 km intervals) detects the P-wave (primary tremor). The obtained seismic wave is analyzed to estimate the epicenter, scale of earthquake, as well as seismic intensity at individual locations in a matter of seconds, before the information is distributed.

The example shown in **Fig. 1** is the results taken 19 seconds after Miyagi Oki Electric receives information of an earthquake occurring, since the information is passed onto Miyagi Oki Electric four seconds after the information is prepared, based on the data obtained in the vicinity of the epicenter 15 seconds after an earthquake occurs. Due to the difference in propagating speeds of the P-wave and the S-wave, the onset of the S-wave occurs approximately 35 seconds later, which allows approximately 16 seconds of available time. Furthermore, if the number of secondary and tertiary observation points, as well as the total number of detection and observation points, are increased the accuracy of information relating to the epicenter and seismic intensity improves but as a consequence the available time decreases[3), 4)].

The Emergency Earthquake Bulletin distributed by the Meteorological Agency is, as described above, extremely effective as a preventative strategy against the risks when an earthquake occurs. However, issues are evident with the bulletin, as described below. High risks relate to the shutting off of gases, containment of chemicals and facilities, as well as termination of operations at semiconductor manufacturing plants, which are in operation 365 days a year. It is for this reason that a blanket implementation of the system has not occurred for the current situation.

a. It is not possible to reduce the incidence rate of false alarms to 0 (20 out of 320 preliminary bulletins are false alarms).
b. Forecast seismic intensity can potentially be off the mark by "1 or 2".
c. Implementation of strategies for locations in the vicinity of an epicenter (inland earthquake) is difficult.

Summary of Disaster Prevention System

In order to resolve the issues described above, the forecasting accuracy has been improved for the three stages of Phase I, II and III, as well as improvements to the reliability and strategies for inland earthquakes devised for this disaster prevention system, which uses the Emergency Earthquake Bulletin developed jointly by Miyagi Oki Electric and REIC. A summary of these systems and control algorithms are described below.

(1) Phase I: Accuracy compensation system for Emergency Earthquake Bulletin issued by Meteorological Agency

This system is intended to improve the accuracy of the maximum seismic intensity by adding information to the foundation of our site (gain of foundation: Represented as a ratio of acceleration response spectrum of the foundation surface and the ground's surface, with a numerical value that indicates the ease of the surface tremors in the ground) to the database for the Emergency Earthquake Bulletin distributed by the Meteorological Agency. The anticipated seismic intensity distribution for an earthquake expected to occur off the coast of Miyagi Prefecture is shown in **Fig. 2**. The figure clearly indicates that anticipated seismic intensity varies greatly for different locations, even when their positions are an equal distance from the epicenter. This is due to the particular characteristics of the foundations, which become minimally required information in order to secure the accuracy of seismic intensity predictions.

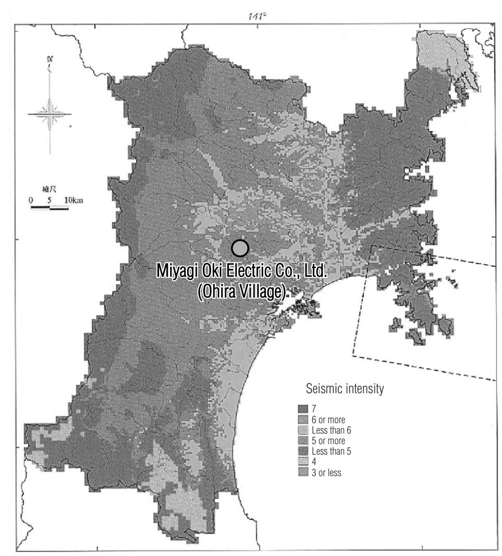

Fig. 2 Forecasted seismic intensity distribution for earthquakes anticipated off Miyagi Prefecture coast (Anticipated epicenter: Off coast of Kinka-zan Island)

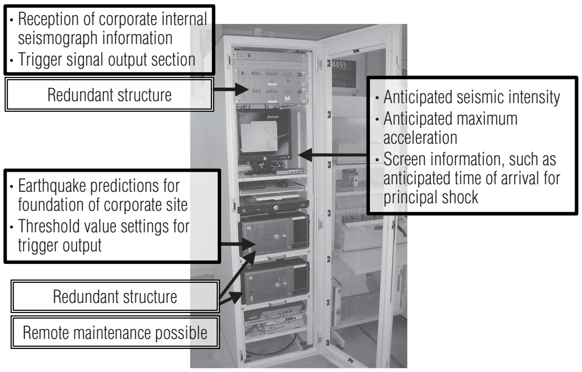

Photo 1 Disaster prevention system using Emergency Earthquake Bulletin

(2) Phase II: Improving Accuracy using onsite P-wave seismograph

A photograph of the disaster prevention system that integrates Phase II and Phase III is shown in **Photo 1**, whereas a schematic diagram of the system is shown in **Fig. 3**.

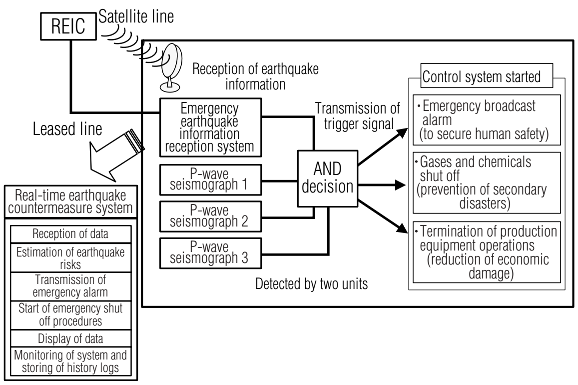

Fig. 3   Summary of earthquake disaster prevention system

The intent of the system is to add a trigger only for the Emergency Earthquake Bulletin of Phase I described previously and to combine the use of information obtained from the P-wave seismograph on site (Miyagi Oki Electric premises), in order to significantly improve the accuracy of earthquake information. The following three aspects are features of the system:

a. Eliminates false alarms through the combined use of the Emergency Earthquake Bulletin and onsite seismograph.
b. Verifies the P-wave arrival using the onsite seismograph.
c. Improves the operational reliability through a redundancy of the system, monitoring of the system and remote maintenance function.

This system features the installation of three P-wave seismograph units, which are installed inside our premises, with the trigger signal transmitted by the AND circuit linked to the Emergency Earthquake Bulletin when two out of three units detect an earthquake (detection of P-wave tremor).

Sixteen seconds of available time on the time chart are shown in **Fig. 1**, however, the available time has been set to ten seconds at the time the final trigger is output out of consideration for the time required for detection by corporate internal P-wave seismographs (three seconds after receiving the Emergency Earthquake Bulletin), with shut off procedures for various corporate internal devices, as well as procedures for suspending system operations. The earthquake predicting accuracy improves even further, since detection data from the observation network of the Meteorological Agency increases during this period.

As already mentioned false alarms and a lack of accuracy have been resolved to a large extent due to the implementation of this system. Implementation of countermeasures when an inland earthquake occurs in the vicinity of the site is not possible, since it is not possible to secure any available time between the reception of the Emergency Earthquake Bulletin and the arrival of the S-wave.

A time chart for the Nagamachi-Rifu fault, which is located in the vicinity of our site, is shown in **Fig. 4** as the source of an earthquake (inland earthquake). In this case detection is made at the first observation point four seconds after an earthquake occurs, whereas the Emergency Earthquake Bulletin can be received nine seconds after the occurrence. The arrival of the S-wave takes place during this period.

For this reason a study was made into a system that predicts the seismic intensity of S-waves directly, based on data obtained from our P-wave seismograph in the final phase.

(3) Phase III: Predicting system using onsite P-wave seismograph

Software for performing direct calculations to predict the S-wave seismic intensity, using data from P-wave seismographs installed inside the company, was implemented for the system that was developed as a complete-type of disaster prevention system. This made it possible to secure the available time to implement procedures for broadcasting alarms, shutting off gases and containing chemicals, as well as suspending facility operations, even though the time to the arrival of the S-wave is only three seconds on the time chart shown in **Fig. 4**.

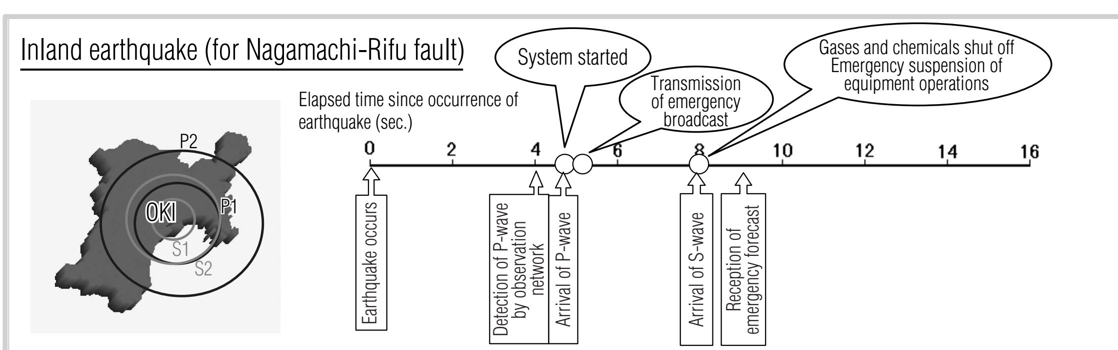

Fig. 4   Propagation time chart inland earthquake seismic waves

Furthermore, other improvements to accuracy were possible for maritime-type earthquakes, through the combination of Emergency Earthquake Bulletin data, while at the same time the implementation of matrix decision-making using two types of prediction system for seismic intensity made significant improvements to the accuracy of decision-making.

Improved operational reliability

An overall summary of the system is shown in **Fig. 5**. All units that comprise the system are implemented in complete redundancy in order to secure 100% of operations in the event of an earthquake, the timing of which is never known in advance. Communication paths have been secured through the Internet and satellite lines for the Emergency Earthquake Bulletin, while operations are assured through the implementation of the redundant system so that contacts and systems A through D remain in operation even if one of the pairs goes down. Software for mutual monitoring resides in systems A to D, making it possible to transmit information to REIC, which is performing maintenance management by email, whenever an abnormality is detected.

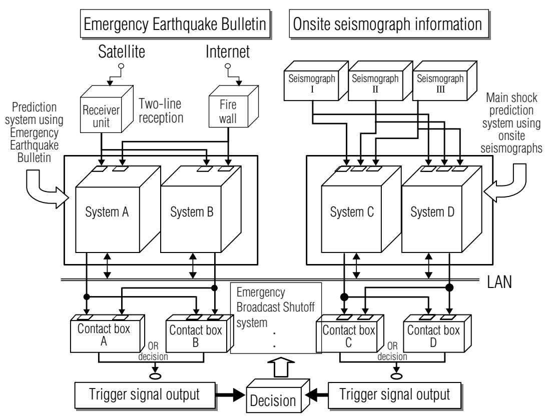

Fig. 5 Overall summary of disaster prevention system

Conclusion

The final system summary diagram for the earthquake disaster prevention system is shown in **Fig. 6**. The corporate internal announcement, "An earthquake is about to occur - please secure your safety" is broadcast when the disaster prevention system chooses 80 gal. The supply of gases and chemicals are shut off via the earthquake shutoff board when the system chooses 120 gal. The use of the S-wave shutoff continues with the shutoff system and operation of the earthquake shutoff board is initiated by the trigger signal from any of these shutoff mechanisms.

As for the facilities located inside the plants, on the other hand, operation of the exposure units for precision processing is suspended, emergency operations are suspended for conveyer vehicles that travel on overhead locations and testers at testing plants are suspended via the signal board. All of these actions are intended to terminate operations in a stable condition prior to the arrival of the S-wave in order to reduce damage, while minimizing the recovery time following an earthquake disaster.

By compensating for the lack of accuracy on the part of the Emergency Earthquake Bulletin, distributed by the Meteorological Agency with onsite seismographs and parallel data processing, incurring enormous costs, reliability of the system was increased to the extent that the system was considered adequate for implementation at semiconductor manufacturing plants. The available time following the anticipated information is short and limited. The value of the system changes significantly depending on the decision to proactively use the available time as "effective time" or do nothing after considering the time to be "too short" to do anything.

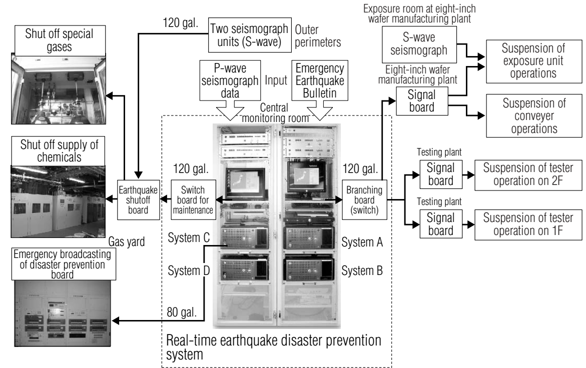

Fig. 6 Earthquake disaster prevention system control system diagram

We intend to fully utilize the anticipated information in a proactive manner and to further evolve such information so as to not only secure the safety of our employees, which goes without saying, but also to reduce damage and recovery operations, thereby offering peace of mind to our customers.

Our activities have been extensively covered by mass media in an example of our proactive utilization of information and introduced into various programs, including the "Close-up Gendai" program broadcast by NHK. We intend to further achieve completeness of Phase III in the future, working to improve the accuracy of seismic intensity, while completing the system to make it adequate for dealing with inland earthquakes as well.

Finally, we would like to express our gratitude to Professor Motosaka of Tohoku University for his enormous guidance relating to disaster prevention systems since before development of this system began.

References

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