5.4 Volcanism

5.4.1 Assessment of hazards and design basis

Based on the Standard Review Plan (SRP), the potential hazards in site vicinity are described in Section 2.2 of SRP. Hence, any potential hazard due to volcano should be included in the Safety Analysis Report (SAR) provided by Taiwan Power Company.

1. The distribution of volcanoes in Taiwan

Taiwan is located at the colliding junction of the Philippine oceanic plate on the east and Eurasian continental plates on the west. From late Pleistocene to the present, Taiwan has undergone significant vertical uplift. The uplift rate is lower in northern Taiwan since it is less tectonically active, while the high uplift rate in eastern and southern Taiwan is consistent with high seismicity due to the collision of the above mentioned two tectonic plates. It is believed that the frequent earthquakes and also some volcanic eruptions during and after the early Pleistocene as well as several offshore volcano eruptions are the results of the Eurasian Continental Plate's subduct eastwardly under the Philippine Sea Plate. The three main areas of volcanoes in Taiwan are as the following:

a. Northern volcano area:
   Mainly Tatun volcano group and Keelung volcano group. Since they are close to Chinshan and Kousheng NPPs, they are described in detail in Final Safety Analysis Report, (FSAR), of these two NPPs.
b. Eastern volcano area:
   Coastal Range, Green Island, and Orchid Island.
c. Western volcano area:
   Including Penghu islands, the foot of mountain in the west side of Taiwan.

Two Pleistocene volcanic eruptions took place in Tatun volcano of northern Taiwan. The last eruption is about 0.8Ma after 1.7Ma of silence since the first eruption. Although these volcanoes may not be entirely extinct as geothermal evidence, no volcano on the Island is known to be active from historical records. The only possible active volcano is offshore Gueshan Island, last eruption about 7000 years ago, which is 20 km away from Lungmen NPP.

As for the submarine volcano, 5 historical submarine eruptions in the offshore areas have been reported. But only the one occurred in 1867 has caused damage to the Keelung harbor due to accompanied tsunami.

2. Volcanic Deposits of Northern Taiwan

The Tatun Volcano Group comprises a series of andesite volcanoes in the northernmost part of Taiwan. The nearest is 15 km north of Taipei City and about 44 km from the Lungmen NPP. About 20 volcanoes and volcanic cones are included in this group. Craters are preserved at the summit of the cones. A few

have been eroded to craterless volcanoes or were erupted as high-viscosity volcanic domes. This group of volcanoes was built by successive eruptions of andesitic flows, volcanic ash and coarse pyroclastic ejecta. They are mainly strato-volcanoes built on a Miocene basement. The most common andesitic lavas in the Tatun Volcano Group are augite andesite, hornblende andesite, and hypersthene andesite or combinations of these.

The Keelung Volcano Group is found in the Miocene rocks on the northeastern coast of Taiwan and to the east of Keelung harbor and about 10 km distance from the Yenliao Site. This group is mainly quartz andesite or dacite flows and some pyroclastics. Ore-forming fluids accompanying the dacite intrusions have deposited valuable gold and copper ores in the host rocks or at the intrusive margin, forming the three famous gold and copper production areas at Chinkuashih, Chiufen, and Wutankeng. And the age of volcanism in Keelung Volcano Group is ascribed to Pleistocene.

3. The records of Tatun volcano eruption.

According to the information provided by Yanmingshan national park, Tatun volcano has two phases of eruption. The last eruption is about 0.8Ma after 1.7Ma of silence since the first eruption.

4. Volcanic Deposits of Southern Taiwan

There is no volcano in southern Taiwan. However, the Worldwide Volcanoes in USGS website did mention a minor submarine volcano eruption event dated 1854, which is located somewhere 45 km away from Maanshan NPP.

5. The prediction of volcanic eruption

Earthquake monitoring network have been deployed at the volcano area to detect the distribution of Epicenter, times of earthquake occurrence and change of frequency, etc., in Tatun volcano group. Terrain change is a sign of volcanic eruption; Geysers around the volcano are also a good indicator. The sign of volcanic eruption is much obvious than earthquake. The sign can be detected days or even months before the eruption. Therefore, people can easily prepare for and avoid the danger caused by volcanic eruption.

6. The volcanic design basis for NPPs in Taiwan

As stated, since there is no active volcano in Taiwan Island, the only possible effect to the nuclear power plants is the tsunami caused by the eruption due to submarine volcano. The 1867 submarine volcano eruption which occurred in northeastern offshore somewhere 134 km NE away from Keelung harbor is used as the design tsunami for Chinshan, Kuosheng and Lungmen NPPs.

7. The evaluation of the offshore Gueshan Volcanic Hazards

Although the offshore Gueshan Island (20 km to the south of Lungmen NPP) is an

active volcano by definition, the island belongs to a part of western extension of Okinawa Trough, and the last eruption is about 7000 years ago. A study in 2001 showed that there is no sign/symptom of volcanic activities found, and due to the wind direction and the island most east cape (Cape San Diego) provide a sound natural barrier to the Lungmen NPP. Recently, there are many submarine volcanoes found around that area, 50~100km to the east of Gueshan Island. But it is judged to be of no potential threat to the safety of Lungmen NPP.

The water around is less than 200 m, therefore even there is a submarine volcano eruption in that area, it will not result in a controlling tsunami hazards.

5.4.2 Assessment of robustness of plants beyond the design basis

Volcanic hazard is considered to be the phenomena related to volcanism that may affect site suitability or the design of a nuclear facility. The volcanic factors/phenomena per the latest IAEA volcanic safety guide SSG-21 are considered in the site specific volcanic hazard assessment as the following:

.

Factors	Possible effects on facility and human	Measures	Related Procedures
airborne lava fragment or tephra fallout	1. Reduce visibility 2. Respiratory injury and discomfort 3. Polluting reservoir 4. affect facilities' operation	1. Collect the latest information of volcanic ash or tephra fallout 2. Perform emergency filter bed ventilation operation for main control room 3. If the pump house CWP water intake was affected, reduce power according to the vacuum condition 4. Enhance the monitoring and cleaning of GT/EDG intake and outlet. 5. The important equipment of reactor is located inside the building, thus the direct effect would be minor.	1. Main control room, computer room ventilation and air conditioning system (304.6) 2. Main control room ventilation and air condition system failure (504.10) 3. Pump house water intake blocked (505.8)
pyroclastic flows	1. Combined with hot air, hot ash and debris flow down with destructive force 2. Deposition, the ash, dust and fragments will overlay and consolidate on the	1. Monitor or collect the latest information of pyroclastic flow. 2. If off-site power is lost, then follow the procedure of Loss of Off-site Power (345kV and 69kV system failure) to react.	1. Loss of Off-site Power (345kV and 69kV system failure) (520) 2. Reactor emergency shutdown (207) 3. Scram Recovery

	land. 3. Respiratory injury and discomfort	3. For oil tank, spray water to decrease temperature and clean deposition. 4. Performing site fire patrol. 5. Enhance the monitoring and cleaning of GT/EDG intake and outlet. 6. Perform emergency filter bed ventilation operation for main control room	checklist (OPER-03) 4. Recovery after scram (208) 5. Main control room, computer room ventilation and air conditioning system. 6. Main control room ventilation and air conditioning system failure.
lava flows	1. Flow slowly 2. Streams at and troughs near the site would mitigate the effect.	1. Monitor or collect the latest information of lava flow. 2. Confirm and fill the raw water reservoir and second pump stations at full capacity in advance. 3. Cool the suppression pool as much as possible in advance. Examine each available rescue and mobile equipment. 4. If there is possibility of safety concerns or loss of off-site power, maintain reactor in cold shutdown condition in advance	1. Maintain shutdown (204) 2. Shutdown/cold shutdown checklist. (OPER-05) 3. Loss of Off-site Power (345kV and 69kV system failure)
mudslide, slope instability	1. Eruption causes fracture and layer slope and slide 2. Buildings collapse 3. The sites located on bedrock, thus the layer slide has limited effect. 4. 345kV and 69kV power system have relatively large effect.	1. Enhance the monitoring of 345kV power system. 2. Enhance the monitoring of 69kV power system.	1. Loss of Off-site Power (345kV and 69kV system failure). 2. Reactor emergency shutdown 3. Scram recovery checklist. 4. Recovery after scram
lahar flow	1. Flow combined with rock fragment and	1. Monitor or collect the latest information of lahar	1. Crisis management and reaction

	water. 2. Seems like mud slide, the lahar flow is the erupted fragment deposit on the slope and flow or collapse due to rain or earthquake.	flow. 2. If government issues the landslide alert, then establish the crisis management and reaction task force. 3. maintain reactor in cold shutdown condition in advance. 4. If off-site power is lost due to the collapse of high voltage tower, then follow procedure 520 Loss of Off-site Power (345kV and 69kV system failure).	instruction (106.9.4) 2. Loss of Off-site Power (345kV and 69kV system failure). 3. Reactor emergency shutdown 4. Scram recovery checklist 5. Recovery after scram 6. maintain shutdown 7. Shutdown/cold shutdown checklist.
new fumarole	1. Close to origin crater. 2. Affecting factors are the same as eruption of Tatun volcano group.	1. Monitor or collect the latest information of fumarole. 2. If lost of off-site power, then follow the procedure Loss of Off-site Power (345kV and 69kV system failure) to react	1. Loss of Off-site Power (345kV and 69kV system failure). 2. Reactor emergency shutdown 3. Scram recovery checklist 4. Recovery after scram
Volcanic missiles	1. Ejection of rock 2. The protection of missiles has been considered in the design of the plant, so the rock ejection has limited effect. 3. 345kV and 69kV power system have relatively large effect	1. Enhance the monitoring of 345kV power system. 2. Enhance the monitoring of 69kV power system.	1. Loss of Off-site Power (345kV and 69kV system failure). 2. Reactor emergency shutdown 3. Scram recovery checklist 4. Recovery after scram
Volcanic gases	1. Volcanic gas comes from larger quantity lava flow. 2. Spread with soil. 3. Corrosive and poisonous 4. Effect to human and facilities.	1. Staff stays indoor. 2. Launch backup gas treatment system. 3. Perform emergency filter bed ventilation operation for main control room	1. Backup gas treatment system (304.4) 2. Main control room, computer room ventilation and air conditioning system 3. Main control room ventilation and air

			conditioning system failure
Landslide, tsunami	1. Effect area is smaller for landslide. 2. The damage and effect area is larger in tsunami hazard but we still have time to issue the alert.	1. If the automatic reactor trip system initiated and CWB (Central Weather Bureau) issues the tsunami warning, follow procedure: Ultimate Response Guideline.	1. Ultimate Response Guideline
meteorology events	1. The meteorology events after volcanic eruption. 2. Potential hazard of high pressure air impact with thunder flash and storm. 3. 345kV and 69kV power system have relatively large effect	1. Enhance the monitoring of 345kV power system. 2. Enhance the monitoring of 69kV power system.	1. Loss of Off-site Power (345kV and 69kV system failure). 2. Reactor emergency shutdown 3. Scram recovery checklist 4. Recovery after scram
ground deformation	1. Eruption causes fracture and layer slope and slide 2. The site locates on firm rock, thus the layer slide has limited effect. 3. 345kV and 69kV power system have relatively large effect	1. Enhance the monitoring of 345kV power system. 2. Enhance the monitoring of 69kV power system.	1. Loss of Off-site Power (345kV and 69kV system failure). 2. Reactor emergency shutdown 3. Scram recovery checklist 4. Recovery after scram
related hazards induced by volcano or earthquake	1. Hazard relevant to earthquake. 2. Hazard relevant to change in pressure and tensor.	1. If the automatic reactor trip system initiated and CWB (Central Weather Bureau) issues the tsunami warning, follow procedure: Ultimate Response Guideline.	1. Ultimate Response Guideline
hydrothermal and ground water	1. Hot liquid causes steam eruption result in rock launching and	1. Enhance the monitoring of 345kV power system. 2. Enhance the monitoring of	1. Loss of Off-site Power (345kV and 69kV system

anomalies	mountain slide. 2. Ground water disturbed result in volcanic mud flow, ground settlement and edge slope instability. 3. 345kV and 69kV power system have relatively large effect	69kV power system.	failure). 2. Reactor emergency shutdown. 3. Scram recovery checklist 4. Recovery after scram