4. Assessment of earthquake and tsunami damage

(1) Importance of incorporating combined rupture of multiple seismic source areas

This earthquake was an extremely huge event with a magnitude of 9.0. The focal area extending above 400 km long north-south and about 200 km wide east-west caused multiple ruptures of seismic sources starting in Off-Shore Miyagi Prefecture and propagating to the north, Off-Shore Iwate Prefecture, and to the south, Off-Shore Fukushima Prefecture and Off-Shore Ibaraki Prefecture. On this basis, importance of considering possible combined rupture of multiple seismic source areas was re-recognized regarding the evaluation of seismic ground motion. The same agenda was also recognized important regarding the assessment of the size of associated tsunamis.

(2) Importance of incorporating of exceedance probability for design basis seismic ground motion and design basis tsunami, defense in depth design, and residual risk assessment

Ground motions in this earthquake observed at some NPS exceeded the standard seismic ground motion in certain period ranges. The Regulatory Guide for Reviewing Seismic Design states that occurrence of a seismic ground motion exceeding standard ground motion can not be denied. In this context, the exceedance probability of standard seismic ground motions determined from the current procedure should be examined as to its appropriateness in terms of the safety goal to be achieved.

At Onagawa NPS, it was confirmed that the measures taken to protect the seawater pump system from inundation were appropriate even under uncertainties required for consideration in the Tsunami Assessment Method by the Japan Society of Civil Engineers (2002). At the Tokai Dai-ni NPS preventive actions were taken to protect the seawater pump system from inundation based on recognition of the uncertainties. At Fukushima Dai-ichi NPS, some actions were taken to lift seawater pumps. In the attack of the tsunami, Onagawa plant and the Tokai Dai-ni plant where inundation was slight and light enough were able to avoid total loss of the terminal heat sinks. At Fukushima Dai-ni Plant, the heat sink of the unit 3 were saved and functioned. In contrast, Fukushima Dai-ichi plant was inundated heavily beyond its tsunami protection capabilities, and lost all of them. This has led to recognition of need for comprehensive restructuring of the tsunami protection that will ensure defense in depth of NPS.

On this basis, it was recognized essential to take actions according to the context of the

Regulatory Guide for Reviewing Seismic Design, including determining design basis tsunami with appropriately large return period based on probabilistic tsunami hazard assessment, apply it to actual tsunami protection design, taking actions to cope with beyond-design tsunami, and validating the total system through the risk assessment in the light of defense in depth to realize required safety goal.

(3) Significance of diversity

Based on the damage caused by this tsunami, it can be seen that, of safety systems of redundant configuration, those safety systems having diversity contributed much, remaining operational, to defense against the tsunami hitting. Therefore, the significance of seeking diversity in constructing safety systems of redundant configuration has been seriously re-realized.

(4) Significance of measures against tsunami scouring and wave force

This tsunami caused the ground foundation of general harbor installations to be scoured by the tsunami run-up and backrush, resulting in collapse. The main units of harbor installations were also knocked down by the strong wave force. This has led to the recognition of significance of taking into consideration the severity of destructive power of wave force and scouring in designing NPSs, for the purpose of defending them against design basis tsunami by drawing on coastal structures. Furthermore, it has also been seriously recognized that, in order to prevent NPSs from being inundated and submerged by a tsunami above the design basis tsunami, the severity of destructive power of the run-up tsunami should be fully considered.

(5) Enhanced measures for seismic and tide level observation systems

During this earthquake, the records of acceleration time history at some NPSs were not fully secured, being cut off after approximately for 130 to 150 seconds. Functional failures in NPS seismic observation systems were also found in the Chuetsu-Oki Earthquake, and therefore, an in-depth study should have been done into maintaining the functions of the systems.

For the tide level observation systems, the measure ranges of tide level are not enough, and also, an in-depth study should have been done into maintaining the functions of the systems.