Need of on field-Seismic Re-evaluation Studies for Existing Nuclear Power Plants

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Abstract— Solutions for Sudden release of energy in subsurface through fault movement have become worldwide challenge for policy makers, decision makers, technical personnel and public. In order to ensure the stability of the site of nuclear power plants, detail site studies are performed to ensure its safety against external hazards specially earthquakes. Lot of guidance and studies are available internationally to conduct detailed site studies for a proposed site, however, to ensure seismic safety of existing NPPs there is need to conduct on field re-evaluation studies so that seismic safety of existing NPPs could be ensured. Currently nuclear safety is controlled by strict regulatory requirements, proven technologies, quality assurance, international codes and standards, implementing defense in depth strategy and international and national experience feedback. Usually siting of NPPs is preliminarily based on deterministic studies supplemented with other site specific, local and regional studies. Recent accidents at Fukushima have shown that there is a need to think for multiple scenarios through continuous on field seismic re-evaluation and probabilistic studies from time to time. On filed seismic re-evaluation studies if conducted in an iterative way is assumed very useful in reducing geohazards specially earthquakes which has been ignored in past. This paper will focus on importance of on field seismic re-evaluation study and its advantages in reducing effects of geohazards specially earthquakes for existing nuclear power industry.

Index Terms— IAEA, OBE, SSE, NPP, LOW, ON, KKNPP

1 Introduction

Earthquake safety means that the processes in the reactor, despite the damaging earthquake event, remain under control and there is no radioactive escape to the enviro ment. Earthquake safety is easy to understand in terms safe shut down earthquake (SSE) and operating basis earthquake (OBE). Because these two levels of earthquakes are responsible for design of NPP for earthquake. The earthquake safety of the nuclear plant is guaranteed if the required number of safety-relevant systems remains functional after the earthquake. Therefore, an earthquake investigation covers not only the site evaluation process but also the safety-related system and equipments.

2 Role of Siting in Enhancing Earthquake Safety

Site evaluation of nuclear power plants is the initial step towards safety of nuclear power plant both against external and internal hazards. Effective siting offers defence against many hazards which are varying in nature for various designs and places and earthquake is considered very influencing hazard and had resulted in breaking different plant barriers in past. Now a day's siting demands very detailed investigations due to recent natural hazards and site behavior in different countries to ensure safety of the public and environment.

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In context of earthquakes, behavior of site is very important to consider which requires regional ,local and site specific information(updated from time to time) to evaluate earthquake potential. Earthquake is considered very important effecting phenomenon due to its uncertain occurrence. Regarding earthquake, the main objective of siting is to see its effect on NPPs system structure and components (SSC) and vice versa. It is now being considered that Siting process should be an ongoing process with the life of NPP and not a onetime process. Because nature of site and external hazards vary from time to time, specially in case of a big earthquake various changes can be observed if not re-evaluated regularly & properly and can damage in future like Kashiwazaki–Kariwa plant (KKNPP) , Fukushima are best examples to understand. Usually it is observed that most of earthquake studies are performed up to 150km for a new site, but it is seen that earthquake effects are beyond this limit and triggering of tsunami has made this more complicated and devastated. On field Re evaluation studies of site are very important and should be conducted from time to time because after or before an earthquake there are various factors that affect seismicity and are needed to re-evaluate in the field.

3 Factors Affecting Seismicity

Seismicity of an area is not controlled only by a mega earthquake or already existing faults. There are many other factors which could cause seismicity, such as:

After any mega earthquake, local geology and seismicity of the area could be disturbed and change which can result in extension of already existing faults geometry like in their length and rupture.

If there is continuous ground water penetration or there is any other fluid injection or withdrawal, reservoir loading and like other phenomenon in nearby areas could activate the faults.

Stresses generated after any big earthquake could affect the faults attitude and can activate some other faults which could produce any seismicity in future and are not considered before. This happened in case of Fukushima accident as well.
Low seismicity areas are also required to be considered in detail for seismic hazard because only low seismic records of history are not enough. Time to time Field investigations is necessary to have the current status of the existing field evidences. The Kobe earthquake in Japan is a classic example that how a low seismic area can bring an earthquake of large magnitude.[1].
International experience shows that once site evaluation had been completed and plant has been constructed & operated, there is always chance of missing some important information or the surfacing of some new faults around the site with the passage of time. Hence there is need to re-evaluate the site to confirm and update the already existing information.
Recent studies have shown that interplate earthquakes are very frequent in different regions due to ongoing movement of plates which ranges up to 7 cm/year with strain accumulation rate of approximately $3 \times 107/y$ along plate boundaries. [2]. This interplate tectonic is becoming major cause for changing intraplate tectonics due to which stresses are accumulating and change interseismic phase of earthquakes. Although number of earthquakes with in plates are less but plates continue to move due to which plate boundaries change over geologic time and weak boundary regions become part of the interiors of the plates. These zones of weakness within the continents can cause earthquakes in response to stresses that originate at the edges of the plate or in the deeper crust. Due to these continuous motions of the plates and accumulation and release of stresses, some faults can be generated or triggered which could not be observed at the initial phase of site evaluation. Therefore there is need to monitor earthquakes both in field and instrumentally in a continuous way so that up to date strategy could be developed.

4 Earthquake safety through NPP design

After March 11 earthquake and tsunami that devastated Japan's Fukushima Daiichi nuclear power station, concerns about the safety of nuclear power plants through its siting, design, construction and operation have increased considerably. At the moment, different types of NPPs with different designs are operating in the world such as PWR and BWR etc. [3]. Design of NPP plays very important role in ensuring earthquake safety but here it is important to highlight that siting of NPP is fundamental thing that can ensure present & future safety of NPPs against external hazards. It is observed in many countries that siting studies are usually based on historical records and are based on any single big scenario whereas latest studies or changes that may occur in the field are not observed regularly. Siting with respect to earthquake in accordance with updated or on site re-evaluated studies is very important for safe operation. In most cases, earthquake safety in design is based on deterministic seismic hazard analysis (DSHA, single scenario) and determination of OBE and SSE are designed accordingly. But recent earthquake accidents have shown that this is time to go beyond these studies. Now a site can behave very differently and it is required to investigate for diverse scenarios, probabilistic seismic hazard analysis (PSHA) in this case is very effective and may be used with Re-evaluation process. Following studies can make design more reboust and resistant;

- Detailed site specific investigations both for existing (on regular basis) and future nuclear power plants.
- Siting should be based on historical & most recent and updated data with state of the art technology.
- Seismic re-evaluation in field from time to time for existing NPPs.
- There is need to consider multiple earthquake scenarios (PSHA) along with single scenarios (DSHA).
- Determination of OBE and SSE should not be based on DSHA only it should be evaluated through PSHA and other probabilistic studies as well.

Consideration of SSE and OBE should not be considered exclusively only for primary or reactor side of NPP but also for secondary side specially diesel generators building etc, because it is observed that there is very less probability of damage to primary side directly but secondary side which may trigger damage to primary side like in case of Fukushima should also be considered.

5 Seismic-Re-evaluation as a tool to enhance earthquake safety of existing NPPs

Regular On field Seismic re-evaluation for NPPs has been ignored in many countries despite of earthquakes and only initial studies during the siting phase of new installation have been taken into account. An earthquake of magnitude 6.8 and epicenter at 16 km north of the Kashiwazaki-Kariwa Nuclear Power Plant (KKNPP) on July 16, 2007 in Japan resulted fire, leaks of radioactivity and jamme of control rod in Unit-7. Although this radioactivity release was not so concerning even then failures and unanticipated events that occurred at the reactor after the earthquake have important implications for nuclear safety worldwide. It is important to mention here that this earthquake not only highlighted the lack of earthquake studies of KKNPP but also the lack of in time execution of emergency planes in case of earthquake damage. Following reasons are thought to be responsible for KK plant earthquake. "[4], [5]".
The design value adapted for KKNPP was on the basis of Japanese old guidelines which never anticipated such a higher PGA value. Seismic hazard for the site was defined in terms of S1 "maximum design earthquake," which is a less intense earthquake and is based on historical records and S2 earthquake, which is an "extreme design earthquake", is derived from seismo-tectonic structures and active faults. These studies were thought quite enough to ensure earthquake safety of KKNPP but after earthquake, peak ground acceleration was found two-and-a-half times greater than what was assumed

for the S2 earthquake." To investigate the reason of this exceedance, a study was conducted at Hiroshima Institute of Technology and Nagoya University in which data provided in Tokyo Electric Power Co.'s (TEPCO) license application was re-evaluated and indicated a fault five times longer than the one TEPCO identified. Also Between 1979 and 1985, during Filed study, TEPCO found four small faults off the coast of Kashiwazaki-Kariwa, but concluded that they were either inactive or unimportant. However, Nakata and Suzuki believe that three of these small faults constitute one 36-kilometer long fault, which is probably active, too. [5]. Such type of inconsistencies shows the importance that how much re-evaluation of site, its surroundings and data is required from time to time. As a lesson from this event it is also easy to understand that sometimes inconvenient or data which is difficult to acquire is ignored due to some reasons which could result such kind of incident.

In case of Fukushima accident a huge debate is going on about the causes of this accident but root cause is yet to be fixed and some questions like. "Why Fukushima site is not re-evaluated regularly in the presence of large and frequent earthquake" need further discussion. If we look on history of Japan specially Fukushima site following major tsunamis are very important;

In 1933 very strong tsunami hit the coast of Sanriku. The earthquake of magnitude 8.4 occurred on March 3, 1933, this time also the quake caused heavy damage and landslides, it was then followed by a 21m high tsunami; in sum more than 6000 people died.

In May 1960 a tsunami generated by an earthquake off the coast of Chile reached the coastline of Hokkaido, causing havoc on the island of Okushiri, and 142 people were killed. Okushiri was hit again in more recent years in July 12, 1993 and an earthquake of magnitude 7.8 caused a 6-10 m high tsunami that hit the small island to the west of Hokkaido. [6].

After studying earthquake & tsunami evaluations for Fukushima site it may be inferred that;

11March earthquake (Mw =8.9) is unique in this region. Although this megathrust is thought to be responsible for the above mentioned earthquake, however, since 1973 about nine times different earthquakes occurred along this megathrust ranging from 7.7 to 7.8 Mw. The maximum earthquake potential estimated for this megathrust was 8.25Mw. But probability of an earthquake of magnitude 8.2 along this megathrust is determined 20% over the next 30 years. And probability of earthquakes between 7.7-7.9Mw along "Miyagi offshore" which is close to Honshu is estimated 80 %to 90% over 30 years. But the interesting fact is that this probability was fulfilled on March 9, 7.8Mw Miyagi earthquake which is considered as foreshock of most deadly 11 March (8.9Mw) earthquake. [7]. This discussion shows that if on field seismic re-evaluation studies would had been carried out regularly, the authorities could had sorted out the value of 8.9Mw which wreaked havoc in Japan. In light of above discussion it is revealed that seismic re-evaluation of site is very imperative to decide about future of our NPPs with respect to earthquakes and its possible damages especially on secondary side.

6 NEED OF EARTHQUAKE SAFETY THROUGH ON FIELD SEISMIC RE-EVALUATION AND ROLE OF IAEA IN FUTURE.

Main objective of over all nuclear safety is to prevent public, and environment from nuclear and radiation accidents and to limit their consequences. In present time nuclear safety is controlled by strictly regulatory requirements, proven technologies, quality assurance, international code and standards, implementing defense in depth strategy and international and national experience feedback. Nuclear safety is ensured on the basis of safety concepts which depends on estimations of internal hazards (internal flooding, pipewipe, fire etc) and external hazards (earthquakes, natural flooding, tsunami etc). These estimations are established on the basis of available technical knowledge, international and national guidelines and experience feedback etc. As it has been observed in case of Fukushima that how much radioactivity is released and how it has affected people, economy etc. So earthquake safety is the key which should be kept in mind both on primary and secondary side of NPPs. Since it is observed that with the passage of time regional and local site conditions changes due to various geologic and seismic phenomenon, so are needed to be monitored and re-evaluated in the field. Especially earthquakes are hidden forces which are required to be monitored effectively, regularly and according to up to date information. IAEA being focal point of nuclear safety worldwide has key role in supporting earthquake safety of NPPs worldwide and especially in those countries where earthquake potential is high. IAEA has published requirements, guidelines and technical documents which addresses how to do site evaluation and how to design NPPs accordingly. But specific guidelines regarding on field seismic reevaluation still needs to be evolved. In case of on field seismic re-evaluation for existing nuclear power plants, it is believed that seismic re-evaluation is limited only after any big earthquake or an analytical approach is used to determine the earthquake level without any field investigations. But as it is mentioned in above discussion that seismic re-evaluation should not be limited to any event rather it should be done on regular basis and may be a part of (safety analysis report) SAR like (periodic safety report) PSR typically after specific interval of time. As per IAEA guidelines,

"Regardless of any lower apparent exposure to seismic hazard, and as a good safety practice, a minimum of 0.1g peak horizontal ground acceleration should be adopted for all plants as a value to scale the appropriate response spectra which corresponds to the seismic level 2 (SL-2) earthquake." "[8], [9]". This approach highlights importance of earthquake hazard that even there is a very low chance of earthquake still there is need to apply 0.1 g value, Kobe earthquake is best example which highlights the need of investigating low seismic zone for any big earthquake. The same approach should be adopted regarding on field seismic re-evaluation in the field. Although if there did not occur big earthquakes, even then site is required to be re-evaluated at a specified interval of time by a team of experts like Seismologist, Civil Engineers, Geologist, Geophysicists etc.

7 CONCLUSION

During the literature review it is perceived that all emphasis regarding geologic and seismic investigations is for the proposed site. However, there is massive need to do the field investigations at a specified frequency for the existing NPPs. After Japan earthquake, the importance of seismic re-evaluation in the field should be considered as matter of urgency. On field seismic Re-evaluation should be continuous process and not one time study. International organizations should play their role more effectively and there is need to revise site related studies from time to time to understand geohazards. Use of international experience feedback with involvements of related stakeholders can be effective in reducing potential damage. For this purpose, international seismic safety centre (ISSC) should come forward with technical guidance & support and to create awareness in member states regarding seismic on field re-evaluation studies from time to time. International forums like IAEA can play vital role through its safety standards and technical reports based on lessons learned for on field Seismic re-evaluation studies.

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