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A Review on Fukushima Nuclear Disaster and Recommendations for the Present and Future Nuclear Power Plant

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Abstract: *Severe nuclear accidents have been few and far between but their chronicle will help preclude forthcoming cataclysms and will reveal the importance of nuclear safety. This study deals with the review of Fukushima Nuclear Disaster which was rated level 7 on International Nuclear Event Scale (INES). This accident was not a Japanese accident, in fact, it occurred in Japan. Due to excessive external power and battery run out the overheating fuel in the plant's operating reactor cores led to hydrogen explosions that severely damaged three of the reactor buildings. The sequence of the event has been given in a chronological order. Event analysis according to reactor unit has also been given. Radiological release and the health hazard from the radiation exposure have been discussed quantitatively. Economic effect of the disaster has also been mentioned. Fukushima Nuclear Disaster is an exemplary accident that teaches us to take a stance against the beyond-design-basis flaws. Operational nuclear power plants can be safer and more reliable from the lessons learnt from such an accident. Some recommendations are given which can be considered for the current plants and especially for the plants which are under construction or under plan to be constructed to ensure the safety and reliability.*

Key words: *Fukushima Nuclear Disaster, Risk, DBA, Lessons Learnt, TEPCO*

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I. Introduction

The largest Thoku Region Pasicific Coast earthquake(Richter scale 9) was occurred on Friday, March 11, 2011, at 2:46 p.m. (Japan time)[1].This is the largest earthquake in the recorded history of Japan, occurred on the east coast of northern Japan. Japan is placed along the Pacific Ring of Fire, an area that rings the Pacific Ocean and is characterized by mountains, volcanoes, and faults. Following the earthquake on Friday afternoon, the nuclear power plants at the Fukushima Daiichi, Fukushima Daini, Higashidori, Onagawa, and Tokai Daini Nuclear Power Stations (NPSs) were affected, and emergency systems were activated automatically. As indicated in Fig. 1[2], five NPSs, located on the northeast coast of Honshu, Japan's largest island, are in the vicinity of the earthquake/tsunami. They are, going north to south, the Higashidori NPS, the Onagawa NPS, the Fukushima Daiichi NPS, the Fukushima Daini NPS, and the Tokai Daini NPS. These NPSs are the ones that were primarily affected by the earthquake/tsunami. The earthquake caused a tsunami, which hit the east coast of Japan and caused a loss of all on-site and off-site power at the Fukushima Daiichi NPS, leaving it without any emergency power[2]. Due to the damage of the electrical network and emergency diesel generators, it was not possible to provide electricity to cool nuclear reactors and the fuel storage pools, which resulted in numerous explosions and total damage of the Fukushima Daiichi NPP. As mentioned in the NAIIC (2012) report[3]: "The loss of electricity made it very difficult to effectively cool down the reactors in a timely manner. Cooling the reactors and observing the results were heavily dependent on the electricity for high-pressure water injection, depressurizing the reactor, low-pressure water injection, the cooling and depressurizing of the reactor containers, and removal of decay heat at the final heat sink. The lack of access obstructed the delivery of necessities such as alternative water injection using fire trucks, the recovery of electricity supply, the line configuration of the vent and its intermittent operation". The resultant damage to fuel, reactor, and containment caused a release of radiation to the regions surrounding the NPS.

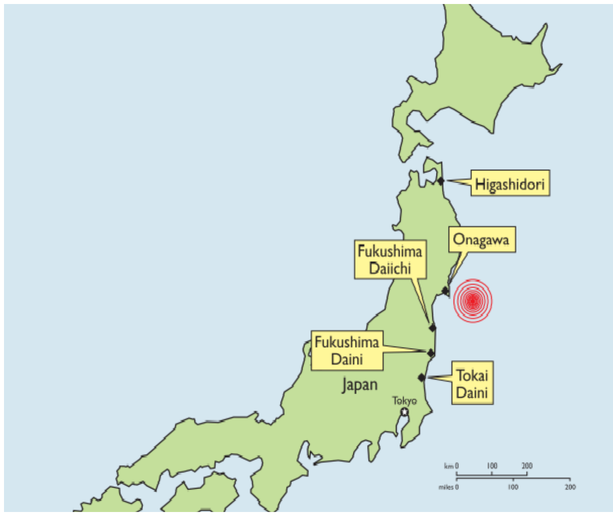

Fig. 1. Japanese NPSs near the earthquake/ tsunami zone(ANS Committee Report 2012)[2]

Estimates vary, but the accident emitted at least 168 times the amount of radioactive cesium 137 as did the Hiroshima atomic bomb, although nobody died of immediate radiation exposure. Mandatory evacuation zones of a radius of 10 kilometers were imposed on March 11, and expanded to 20 km the following day, affecting over 80,000 residents. The disaster was eventually declared level 7 on the International Nuclear Event Scale (INES) -the maximum. In Fukushima, sea water pumped into the reactors and used fuel storage pools created more than 100,000 tons of contaminated water, about a tenth of which was released into the ocean [4].

II. Event Sequence of Fukushima Nuclear Accident[4]

March 11:

It was exactly 2:46 pm (Japan time) when the earthquake occurs. Eventually, as a result at 2:47 pm all reactors loss external power as a designed basis. 40 minutes later, the Tsunami first wave hits and a few minutes later the second one hits. At 3:37 pm, reactors unit 1, 2, 3 all lose power completely. At approximately 4:40 pm reactor 1 core meltdown begins and at 6:00 pm reactor 1 core damaged completely. For the graving situation rises, at 7:03 pm nuclear emergency was declared. An hour later reactor 1 pressure containment vessel damaged (estimated). After about an hour forward, the backup lights restored to operations centers of reactor 1 and 2. At 8:50 pm authority declared evacuation order for 2 km radius around Fukushima Dai-Ichi. Half hour passed by, evacuation area expanded to 3 km radius, 3-10 km ordered to remain indoors, After 9:51 pm, it was estimated that radiation levels of Reactor 1 building started rising.

March 12:

At 12:06 night the pressure levels of Reactor 1 containment vessel begins rising and the plant manager Yoshida orders venting. Half an hour later Prime minister Kan agrees to vent Reactors 1 and 2. Finally at 3:12 am Chief Cabinet Secretary Edano announces venting to press. At 4 O'clock Major aftershock of 6.6 centered on northern Nagano Prefecture. For safety issues, at 5:44 am Prime minister Kan urges 10 km evacuation order and immediately fire truck begins injection of foam water. Between 7 and 8 am, Prime Minister Kan arrives in Fukushima Dai-Ichi and Yoshida orders vent procedure to aim for 9:00 a.m. But at 8:05 am Prime Minister Kan departs Fukushima Dai-Ichi. To visit the site, at 10:00 am TEPCO President arrives at headquarters. At 11:36 am Reactor 3 cooling system stops. However, Reactor 1 vessel pressure decreases, judged to be successful venting and radiation leaked at around 2:30 pm. An hour later, power truck successfully connected to benzene pump and only 5 minutes later, there was hydrogen explosion in Reactor 1 building. At 4:27 pm emergency alarm was given for the radiation rise which was recorded as 1015 mSv per hour. At 6:25 pm Prime Minister Kan orders 20 km radius evacuation. Then Fire truck injects sea water into Reactor 1 at 7:04 pm and Prime Minister Kan orders sea water injection at 7:55 pm.

March 13:

At 2:42 am Reactor 3 high pressure coolant injector stops. In the morning, at 7:40 am Reactor 3 core was exposed according to estimation. And then reactor 3 was manually vented at 8:35 am and at 9:24 am TEPCO determined Reactor 3 vented. Reactor 3 core damaged after an hour passed. In 1:12 noon, Fire truck begins injecting sea water into Reactor 3 and at 10:10 pm Reactor 3 pressure containment vessel damaged (estimated).

March 14:

On March 14, at 11am, reactor 3 experiences hydrogen explosion and damages were observed in reactor 2 venting circuitry. For analysis, reactor 2 pressure and temperature rises were recorded. According to Nuclear emergency report, article 15, at 1:25 pm reactor 2 emergency cooling system became inoperative and at 6:00 pm reactor 2 core was exposed (estimated). Finally at around 8:50 pm reactor 2 internal pressure exceeds maximum specs.

March 15:

At 3:00 am sharp, METI Minister Kaieda reports to Prime Minister Kan that TEPCO wants to evacuate. At 4:17 am, TEPCO President Shimizu visits prime minister's office and at 5:26 am Government-TEPCO accident response joint headquarters was announced. Few minutes later, Kan arrives at TEPCO headquarters. At 7 o'clock morning, reactor 4 building explodes. TEPCO employees other than direct operations crew evacuate to Dai-Ni. After an hour or two, Kan returns to prime minister's residence and at 11, he issues evacuation order for 20–30 km radius. Thinking the situation more grave, at 4:45 pm the U.S. Secretary of State Hillary Clinton states that if accident had occurred in the United States, evacuation zone radius would be 50 miles (80.5 km).

March 16:

Fire in building 4. Reactor 3 emits white steam/smoke.

March 17:

SDF helicopters and fire trucks begin dousing Reactor 3 with water.

III. Event Analysis According To Units

Unit 1: Water level dropped to the top of fuel, fuel temperature rose to 2800°C and caused the fuel to melt and drop to the bottom of the reactor pressure vessel (RPV) at 7 am of 12th March. Containment was vented by 2:30 pm but due to insufficient power it back flowed. Hydrogen produced exothermically by oxidation of the Zirconium cladding in presence of steam and air mixture got ignited causing a hydrogen explosion blowing off roof and cladding [5,6,7].

Unit 2: Pressure vented on 13th and 15th and opening of blowout panel at the top helped avoid hydrogen explosion. A leak on primary containment vessel on 15th caused major radioactive release from the site [5,6].

Unit 3: Failure of water injection system caused fuel to melt and fall on the bottom of RPV. To release RPV pressure successful venting was done on 13th March and when repeated on 14th, events at unit1 were repeated causing hydrogen explosion and a lot of debris [5,6].

Unit 4: Hydrogen of unit 3 reached unit 4 by backflow through shared ducts causing another explosion at 6 am 15th March destroying the top of the building and further demolishing unit 3's structure. Cooling in the following months from external sources kept temperature and pressure of RPV below 100°C and 1bar respectively. Finally TEPCO declared cold shutdown on 16th of December 2011[5,6].

IV. Crisis Time Event Analysis

During the initial time of crisis, neither TEPCO's chairman, widely considered the center of power, nor the president, were at TEPCO headquarters. Since telephone networks were down following the earthquake, neither could communicate effectively with TEPCO headquarters, let alone the Fukushima plant operations center. Neither could return to TEPCO headquarters for more than twenty hours after the earthquake and tsunami. Moreover, the political leadership, led by Prime Minister Kan Naoto was unaware that TEPCO's chairman and president were absent from TEPCO until much later. Chairman Katsumata Tsunehisa was in China at the time of the disaster on a tour with Japanese press and labor leaders, and had no way to return to TEPCO headquarters [4]. Katsumata returned to Japan the following morning. In the meantime, most communications lines were down within Japan, and it is not clear that he was able to communicate effectively with headquarters8. With rail and road transportation to Tokyo closed, president Shimizu traveled to Nagoya, attempting to use a TEPCO affiliated company's helicopter to fly to Tokyo. However, by the time he reached the heliport, it was discovered that the company had neither the equipment nor permits to fly at night. Shimizu and his staff were then able to contact the government for use of a Self-Defense Forces (SDF) aircraft to fly Shimizu to Tokyo. The large C-130 transport aircraft, with Shimizu as the sole passenger, took off towards Tokyo at 11:30 p.m., eight hours after the disaster. Yet, due to a combination of terrible judgment by the Minister of Defense and information failures within the SDF, the plane made a U-turn at 11:45 p.m. and returned to its base in Aichi Prefecture. What had transpired was the following.

Upon hearing that Shimizu would be transported via C-130, the Defense Minister had ordered that all SDF resources should focus on rescue and recovery from the earthquake/ tsunami disaster. The SDF at the time was fully consumed with the disaster, which far exceeded anything it had ever dealt with. After hassle of wrong interpretation and misunderstanding, Shimizu landed at the Tokyo heliport. From there he was stuck in the post-disaster traffic jam that gridlocked Tokyo on March 12. It took him two hours to reach TEPCO headquarters, finally arriving around 10:00 a.m.—almost twenty hours after the disaster. By then, the Fukushima crisis was grave—likely the reactor melted down—and about to experience the first hydrogen explosion. The prime minister's office and TEPCO had been working through the night in an attempt to contain the crisis making a series of critical decisions but not making specific decisions that might help the situation.

The severity of information and communications problems was immediately apparent up to the afternoon of the disaster on March 11 and to the Fukushima plant. It was a design fault that the plant had not sufficient ways to operate under complete loss of external and on site backup. Also, it lacked measures to cope with a breakdown in communication. Mobile communication was not possible due to the devastation of earthquake. Handheld transceivers also failed to work. As a result, the plant manager in charge, Yoshida Masao, was working with very little information. Information from the control panel sensors was mostly unreliable due to earthquake and tsunami damage, and a lack of electric power. To meet the situation, Yoshida had to repeatedly send staff into the plant, near the reactors, to assess the situation. It turned out that the emergency cooling system in Reactor 1, which converts steam into water, had started automatically. However, eleven minutes later, an operator had manually stopped it because it was cooling the reactor faster than the guidelines. Yoshida, unaware that the system had been stopped, was given unreliable instrument readings, and assumed that it was operating. He therefore prioritized cooling Reactor 2 rather than Reactor 1, though in reality Reactor 1 was in far worse condition. At 3:00 p.m. on March 11, Yoshida sent faxes to TEPCO headquarters and NISA (located within METI), officially declaring that a nuclear emergency was likely to occur.At 4:30 p.m., he sent another message upgrading it to "emergency in progress," a status that automatically triggers an evacuation order was also unprecedented[9,10]. Yoshida noted that they were unable to cool the reactors and could not monitor the water levels of Reactors 1 and 2. The implications were serious, since the reactor fuel cores needed to be immersed in water; if the hot core evaporated all the water, the core would be exposed, and fuel core rods would overheat and become damaged—the phenomenon commonly known as a "meltdown." At 4:54 p.m., Prime Minister Kan Naoto issued a two minute statement at the press room saying that the nuclear reactors had stopped and no radiation leakage had been observed. He took no questions. While Kan's statement was true, it did not acknowledge that a report of "nuclear emergency in progress" had been issued by the Fukushima Dai-Ichi plant. Kan's two close aides, Terada Manabu, and HosonoGoshi, both DPJ members, were at the prime minister's residence when KaiedaBanri, Minister of METI, rushed to join them at about 5:45 p.m. Kaieda wanted Kan to immediately declare an emergency [9,10].

Kaieda later affirmed to a Diet investigation commission later that it took time to get Kan's understanding and agreement to declare the emergency[3].One problem was that the prime minister's office lacked the know-how of exactly how to do so, with secretaries and aides busy reading the relevant laws. NISA staff also lacked such operational knowledge. The relevant law was the Special Law for Emergency Preparedness for Nuclear Disasters, which had been formulated after a 1999 nuclear accident at the Tokaimura uranium reprocessing plant in Ibaraki prefecture. The problem with this law, however, was that it did not provide for a nuclear disaster occurring simultaneously with an earthquake/tsunami disaster. It called for a gathering of the Nuclear Safety Commission (NSC), which was to establish an emergency technical advisory group to advise the prime minister. The NSC was comprised of about forty members, and with communication networks offline, all public transportation in the Tokyo Metropolitan area was in gridlock, there was no way to gather the members headquarters[8]. At 7:00 p.m., Kan declared a nuclear emergency to the nation—the first time such a declaration had been made. Though this time the evacuation should had to be ordered but the staff had not prepared for evacuation procedures. Kan and his staff could not gain information about conditions on the ground and it was impossible to set up centres for evacuees due to the paralysis of transportation. At 7:45 p.m., Chief Cabinet Secretary Edano Yukio advised the public not to panic and flee, but to stay indoors and wait [5,6].

V. Radiation Levels

In May 2012 estimates published by TEPCO showed a total of 1020 PBq were released to the atmosphere from 12-31 March 2011 of which 20% came from Unit 1, 40% from Unit 2 (peak on 15 March), and 40% from Unit 3 (peak on 16 March). From 26 March to 30 September 2011 releases to the ocean were about 11 PBq iodine-13, 3.5

PBq Cs-134, 3.6 PBq Cs-137, total 18.1 PBq (or 169 PBq I-131 eq) [5,6]. Among the many fission products released, the main radionuclides were volatile iodine-131 with a half-life of 8 days, soluble caesium-137 (can be taken into the body but does not concentrate in any organ) with a half-life of 30 years (biological half-life 70 days) and caesium-134 with a half-life of 2 years. Cs-137, a strong gamma emitter, can easily be carried in plume, can contaminate and stays long when it lands. Following hydrogen explosions on 12th, 13th and 15th March, radioactive iodine and Cesium were detected in the vicinity of the FDNPS. However, compared to cesium, effects of Pu and U in the vicinity of FDNPS were insignificant [11]. More than 100 seawater samples were collected from the North Pacific Ocean in April and May 2011. All of them detected Cs-134 and most of them detected Cs-134. Activity of Cs-137 ranged from 1 to 1000 Bq m^{-3} with activity ratios of Cs-134/Cs-137 close to 1 proving that the radio cesium originated the [12]. Iodine and caesium were also found in soil core samples collected from the Fukushima prefecture. But their migration to soil layers deeper than 5 cm was limited due to their strong affinity towards humic substances and clay minerals [13]. Cs-137 contaminated soils in large areas of eastern and northeastern Japan, whereas western regions were sheltered by mountain ranges[14]. Only 13% of I-131 and 22% of Cs-137 were deposited on land of Japan and the remaining was either deposited in the ocean or transported out [15]. Most of the Cs-134 (14 out of 15 PBq), Cs-137 was from unit 2. Ten times more iodine was released from unit 2 than unit 1, and unit 3 released half of that from unit 1 [5,6].

VI. Health Hazards Due To Radiation Exposure

Just after the explosion, the maximum external dose recorded was 199 mSv and the maximum internal dose that had been calculated was 590 mSv. The maximum total dose recorded to one worker was 670 mSv, and six workers had received doses in excess of the emergency dose limits established. Although 408 workers had received doses above the normal annual limit of 50 mSv, the average dose for emergency workers was still relatively low and had decreased steadily during the months following the accident. For workers performing emergency work since March, the average total accumulated dose was 22.4 mSv. For the months April through July, the average dose was less than 4 mSv. The total collective dose for all emergency workers was estimated to be 115 person-Sv. In addition to whole body doses, two male employees received significant skin dose (2-3 Sv) while laying electric cables from standing in contaminated water that flooded their boots. Internal radiocesium contamination was a matter of concern after the occurrence of Fukushima nuclear accident. However, a little variation was measured by several hospitals and research institutes which was not worth concerning.

A recent airborne monitoring survey[16] carried out by the Japanese government shows that the surface deposition density of Cs-137 amounts to 60k–300 kBq/m^2 in such densely populated cities as Fukushima and Koriyama (DSCS, University of Tokyo). The fact that the CEDs (Committed Effective Doses) were less than 1mSv [17] in all but 1 resident after February, 2012 already indicates that the average daily intake of radioactive cesium by Fukushima residents must be less than estimated from the deposition density. In fact, the actual intake is significantly less than it was expected.

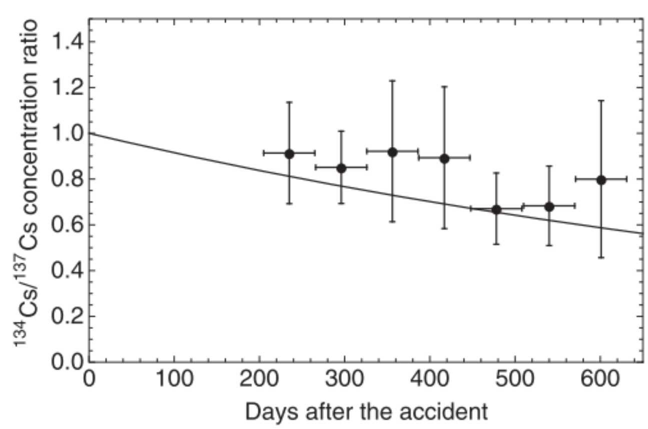

Fig 2: *The ratio of Cs-134 to Cs-137 body concentrations plotted against the number of days after the Fukushima Dai-ichi accident. The solid curve is calculated by assuming an initial Cs-134/Cs-137 ratio of 1 : 1*[17]

VII. Exclusion Zone and Return of Evacuees

At 7:03 pm Friday 11th March a nuclear emergency was declared and at 8:50 pm an evacuation for people within 2 km radius was ordered. By the evening of 12th March it was extended to a 20 km radius. 20 mSv/year criterion was applied to determine return of evacuees in areas having radius greater than 20 km. From the contaminated area of 20-40 km northwest of the plant, 15,000 people were displaced in mid-May taking the total to 100,000. From April 2012, the Ministry of Economy, Trade and Industry (METI) allowed restricted return to regions within 20 km radius around the plant and in portions of the Minami Soma city extending more than 20 km north [5,6]. These regions were further classified into:

- Regions with radiation level less than 20mSv/year were taken off from evacuation.
- Regions with 20-50mSv/year were allowed entrance without precautionary measures and only for specific purposes.
- Regions with radiation levels greater than 50 mSv/year are still restricted to entry except for some special purposes.

In July 2012, METI added Litate village to the evacuation zone. It is 28-45 km northwest of the Daiichi plant and adjacent to the northern part of Minami Soma city. An urgent field survey carried out on 28 and 29 March 2011 showed that volatile radionuclides iodine and cesium were the main components of radioactive contamination. Also, an exposure rate of more than twenty micro Sieverts per hour was observed only in the southern part of the Iitate village[18]. Now, except 10 sqkm area of Iitate and some part of Minami Soma city joining Iitate within the 20 km radius of Daiichi plant that remain fully evacuated, Iitates's citizens are allowed to return without protective gear but cannot stay overnight. By August 2012, people of Naraha town in the south and parts of Okuma-machi in the southwest of the plant were allowed to return in the same way as the citizens of Iilate, making more than half of the originally evacuated area accessible. After August 2013, Futaba, within 20 km radius of the plant, was the only municipality to remain closed to the return of the evacuees. Infrastructure destroyed by the Tsunami was another major factor that limited the return of the evacuees. Most of the 72,800 people who used to live in the towns and villages of Futaba were economically reliant on the plant and were thus mostly affected [5,6]. Nuclear regulatory authority (NRA) continuously measure individual external exposure doses for Fukushima prefecture residents as part of the study on 'Safety and Security Measures towards Evacuees Returning Home (IAEA, 2013)[19].

VIII. Economic effects and political response

FDNPS disaster led to the closure of all the Japan's 48 nuclear power stations, which produced 30% of its electricity[20]. Instead of increasing the value to 40% by 2017 as projected before 2011, it went to zero. The import cost of alternatives to nuclear energy is $40 billion per year [17] and had cost a staggering $204 billion from 2011 to end of 2013[21]. Impact of FDNPS accident[22] and moving away from nuclear energy is enormous and eating away a huge proportion of its GDP.

IX. Discussions and Recommendations

Fukushima nuclear accident is an exemplary instance for the beyond design basis fault of a power plant. The current and upcoming nuclear power plants have much more things to learn from such an accident. The following recommendations may come to use for the current plants and also the plants which are under construction or under plan to be constructed.

- ***Risk-informed approach of regulatory authorities:***

Regulatory bodies of the respective country of the NPP should review the scope of reactor safety design and regulation. This review should consider design bases for natural- hazards and the need for extension of the design basis in a graded manner, using a risk-informed approach. The review should also consider environmental and geographical factors more seriously regarding the setting up of a plant. A risk-informed regulatory approach would have identified the existing design bases of the Fukushima NPPs as deficient. Although addressing low-probability events is very difficult, a risk-informed treatment for natural-phenomenon hazards is necessary. The industry needs to develop severe accident management guidelines (SAMGs) including the manner in which they interface with emergency operating procedures.

- ***Precaution for multiple-unit-site approval:***

Though the high cost and lengthy schedule to obtain site approval are powerful incentives for multiple unit sites, it's recommended that the appropriate regulatory bodies conduct a multiple-unit risk assessment whenever a unit is added to a site. Such an analysis should consider whether the added unit increases or decreases the risk factors. In essence, risk probabilities of running multiple units are needed to be double-checked before approval.

o ***Concern regarding hardware design modifications:***

Surveys and studies regarding the Fukushima Daiichi accident have identified a series of hardware-related modifications after the designed plant ran into operation that may be considered as sensible reasons of equipment failures. For the hardware applicability are plant specific, any generic modification should first be subjected to some form of cost-benefit analysis. Furthermore, if taken one at a time, resolution of these hardware issues may lead to systems-interaction changes. Therefore, an overall systems-interaction study needs to be undertaken when looking at the overall effect of any changes to be certain.

o ***Command and Control and Emergency planning*:**

Sometimes unclear command of chain makes situations worse. Fukushima NPP faced the same crisis just after the accident. The Committee determined that the severity of the Fukushima Daiichi accident was exacerbated by such things. Therefore, it's recommended that the predefined command-and-control system for emergency situations at NPPs be reviewed to ensure the accident emergency decisions to be taken promptly at the proper operational level. The nuclear communities recognize the need for a clear approach to emergency planning in case of a serious accident. Therefore, a committee may be formed for emergency accident minimization. In fact, the chain of command must be able to react swiftly to an accident and emergency planning is essential for current NPPs.

o ***Reanalyzing seismic and flooding effects*:**

NPP should have a committee to reanalyze potential seismic effects and flooding effects using present-day information to determine if safety upgrades are needed. Though, earthquakes are really tough to predict, still the geographic plates pattern, weather pattern, flood timings can help assume any future natural disaster. Moreover, flood management systems should be more improved and the government must look into the issues regarding water resources and evaluate potential enhancements to the capability to prevent or mitigate seismically-induced fires and floods.

o ***Use of simulators and applications:***

The progression of an accident, simulation tools could help identify the most effective strategy to manage a prolonged station blackout or other sequence. High-level and predictable applications can be developed for the predictions of subsequent events under beyond-design-basis conditions before the core damage so that it actually can be prevented in a prompt manner. Application provided information might be utilized in the form of pre-prepared charts or steps may be generated for the actual conditions of the NPP by a faster-than-real-time simulator. Current NPPs, therefore, should develop highly flexible applications and simulations for the sake of post-accident management. Trainees should be introduced in advance to take steps in case of emergency via these application softwares.

X. Conclusion

Any flaws in the design basis of NPP can lead to nuclear disaster like Fukushima. Although the risk of nuclear accident cannot be made zero, it can be minimized by proper 'Design Basis Accident Analysis (DBAA)'.All the accident initiating events with both low and high probability should be considered in the design basis. Historical data for the seismology, geology, hydrology and meteorology should be considered for the long period of time as much as possible. Experience of other countries in the design and operation of Nuclear Power Plant will help the new comer country like Bangladesh in this perspective. A best site selection, appropriate reactor design based on the cite criteria and proper operation will minimize the risk of nuclear disaster which in turn ensure the safety and reliability as well as protection of People and Environment from the harmful effect of radiation.

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