

## **Actions Contributed to Disaster Level Reduction of the Fukushima Accident**

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**Abstract.** In this paper, the actions less known but contributed to mitigate outcome of Fukushima accident in the light of the concept of resilience engineering are described with the emphasis on the human positive contributions. Although accident reports already published mainly focuses on finding persons to be blamed and on finding root causes, there were judgments and actions that reduced the disaster level of the accidents after the tsunami hit the plant and lost almost all methods to save the plant. In this paper, the positive aspects of the efforts made by the TEPCO has been focused and discussed.

### **1 INTRODUCTION**

The accident of Fukushima Daiichi Nuclear Power Plant after the Great East Japan earthquake has caused huge and tragic influences on the people living not only in Fukushima but also on the people living in nearby prefectures by the uncontrolled release of radioactive materials. Although four accident reports already published and the details of accidents have become open, main focus of the reports (except the one by TEPCO) is on finding a person or a company to be blamed and to take responsibility for the disaster (NAIIC,2012) (ICAFNP-TEPCO,2012) (IICFNA,2011) (TEPCO,2012) . Generally speaking, the purpose of an accident investigation should be to reveal the sequences of events and identify the cause of the accident. In the framework of the Resilience Engineering (RE), however, the mechanisms of causing failure are considered to be same as the ones leading to success and the cause of the accident cannot be attributed to a single root cause. In this paper, the focus has been set on the actions

less known but contributed to mitigate outcome of Fukushima accident in the light of the concept of RE.

## **2 HISTORICAL VIEW OF TEPCO**

As far as authors know TEPCO as one of the leading company in Japan, they have paid enough attention on the safety of the nuclear power plant after so called TEPCO problem in which it was exposed as falsifying safety data, including Fukushima Daiichi facility. After this scandal, TEPCO took serious actions against such wrongdoings and became more concerned about the organizational safety.

In the field of human factors, TEPCO had been leading other utilities and had been very positive to take actions for the enhancement of the safety concerning human factors. In terms of regulations, TEPCO had followed all of the rules and regulations instructed by NISA. It seems that it is not fair to claim that TEPCO was the company that kept the nuclear power plant danger and uncontrolled situations by breaking regulatory rules and pursued their own profit. What TEPCO did to enhance the safety of nuclear power plant seemed quite reasonable within the range of common sense. It is easy to blame TEPCO based on the hindsight thought. What decision had been made at stockholders meeting, we wonder, if someone made proposal to build a breakwater against tsunami by spending ten billion JPY before 3.11.

Still, we have to face the fact that terrible accident did occur at Fukushima Daiichi Nuclear Stations, in which the core melt had occurred and huge amount of radioactive materials has released. Hollnagel pointed out the inadequate engineering anticipation or risk assessment during the design phase, in combination with inadequate response capabilities precipitated the disaster (Hollnagel, 2013). Authors totally agree in that overconfidence in the expert anticipation of what might go wrong limited the ability to monitor and respond. However, authors also believe that there were judgments and actions that reduced the disaster level of the accidents after the tsunami hit the plant and lost almost all methods to save the plant. In this paper, the positive aspects of the efforts made by the TEPCO has been focused and discussed.

The state of the plant had drifted toward safety boundary and they could not be aware of the distance to the dangerous region. One possible reason of this unawareness of the danger may be the biased attention on the problem of earthquake and its countermeasures. TEPCO experienced large earthquake that hit another nuclear power station at Kashiwazaki-Kariwa in 2007. The earthquake caused fire at one of the transformers in Unit 3 and gave general public negative impression on the safety of nuclear power plant. Since then, TEPCO had been busy to restart the plants by taking measures to deal with the situations. The countermeasures against earthquake itself had been paid more attentions when the Great East Japan earthquake occurred. NISA ordered all utility companies to prepare revised measures against earthquake and utilities mainly spent their resources on this issue. Although TEPCO may have been

aware of the necessity of any countermeasures against possible huge tsunami, the priority was on the earthquake and the countermeasures against tsunami was postponed before 3.11,2011. The situation of regulatory body had been the same and they also had focused their attention mainly on the earthquake, partly because the social atmosphere required it. Although this kind of cognitive bias is characteristics of human beings, it made the recognition of distance to failure more and more difficult.

### **3 RE VIEW OF FUKUSHIMA ACCIDENTS**

As stated in the previous section, the critics described in the accident reports seem to be unable escape from the hindsight and focus mainly on what went wrong and also on why it happened by finding out flaws in the actions taken in the desperate effort to save the plant. The basic concept in RE insists that the mechanism underlying failure and success is the same and we have to pay more attention on why things go well. It is rather easy to criticize flaws in the actions after we know the overall situations. However, the positive contributions of human actions to mitigate the severe accident should be more emphasized in order to prevent similar accident to happen again. Although there were some problems to be blamed concerning the basic design of safety system and system layout, preparedness against the loss of all external power supply, etc., it should be noted here that the accident had been far more disastrous without the positive contribution of the people who fought against the unbelievable damage caused by tsunami. Several examples of this positive contribution are described in the following.

The Fukushima accident can be categorized into the Irregular Threat, which is quite challenging and unexpected situations with no previous experiences and predefined procedures to cope with. Although there is a discussion whether the possibility of tsunami huge enough to cause critical damage to a nuclear reactor had been recognized by the board of directors of TEPCO, the event happened on 3.11 was totally unexpected from the viewpoint of plant personnel working then. The book written based on the interview of Masao Yoshida, Head Of Fukushima Daiichi Power Plant has revealed the important facts that have not been addressed in any of the previous accidents reports (Kadoma, 2012). Some of the examples of human positive contribution to mitigate outcome are described below.

Just after the huge tsunami hit the plant and lost all of power supply including emergency diesel generators (except one in unit 6), Mr. Yoshida made direction to examine the availability of the fire engine in the power station and asked the head office to arrange fire engines to be sent to Fukushima Daiichi Plant as early as possible, recognizing the possibility of situation in which fire engines were required to inject water into reactor. Although the use of fire engine has been assumed in the Severe Accident procedure, this decision should be appreciated considering the battlefield

situation he faced then.

Second example of human positive contribution is the success of line-up of waterline from a fire engine into the reactor of Unit 1 before the radiation level of containment became critically high. It should be noted here that the decision to perform this action was made by the operators of Unit 1 without the top-down directions from emergency management room dealing with all units in Fukushima Daiichi Nuclear Station. If they had failed to line-up this waterline on this limited opportunity, there was no method left to inject water into the reactor vessel, which may have resulted in far more disastrous situation.

Third example is the successful escape of a tanker landing heavy oil. A tanker was at the site port and was landing heavy oil at the moment of earthquake. When tsunami alert came, operators followed the emergency procedure to stop landing and made narrow escape from the site port before tsunami came. They intentionally cut the oil fence to shorten the time required to escape. If they had failed to escape from site port before tsunami, the ship may have crashed against the reactor building and the leaked oil may have caused uncontrollable fire, which would have made the situation more and more disastrous.

#### **4 DISCUSSIONS AND CONCLUSIONS**

From the view point of RE, the plant personnel definitely knew what to do by using the limited resources remained. They made desperate effort to take emergency measures against all odds. Also, they knew what to monitor and how to monitor, but there were no way left to measure important parameters in the control room because of the total loss of sensing capability. (Later, they succeeded in reviving limited sensing capability by using battery taken from cars.) Under such hopeless situations, they knew what the consequences would be and tried to take possible actions to mitigate the outcome of accidents. Although TEPCO may have lacked in the resilient characteristics in the long-term perspectives, the people in sharp-end, who dealt with totally irregular threats and managed to avoid worst possible plant situation, should be appreciated for having higher resilience.

It should be noted here that there are many “should-have’s” in the accident reports based on hindsight. The focus of the accident reports is biased against people who actually made considerable effort and succeeded in avoiding worst possible situation. Lessons learned from such hindsight thought may not contribute to enhance safety in the future. We should pay more attentions on the human positive contribution to mitigate outcome of the accidents and on why things went well.

The present paper focuses on the two important aspects in resilience engineering. One is the difficulty in recognizing distance to the safety edge when organization seemed to pay attention to safety extensively. The questions; why we could not insist the risk of tsunami and why we overlooked the risk in the face of the evidence; these are the questions we have to find the answer for.

The other is the human positive contribution to mitigate the consequences of the disaster. The detailed analysis considering the human cognitive characteristics has been performed to find that there were many human actions to be praised considering limited resources and psychological conditions as well as negative ones emphasized in the accident reports.

In this paper, the trade-offs in long-term and short-term perspectives have been focused concerning the Fukushima accident. For long-term perspective, the difficulty in decision of prioritization in selecting required countermeasures against possible threats under the trade-off situations has been emphasized. It is pointed out that the existence of cognitive biases in recognizing risk had misled the decision to put the priority more on the countermeasures for enhancing structural tolerance for earthquake while the countermeasure for tsunami left untouched.

For short-term perspectives, the difficulty in managing simultaneous events under the limited resource situation is described with the emphasis on the appreciated actions that contributed to the mitigation of the disaster. The focus has been set on the successes in dealing with trade-offs among required actions under severe and desperate situation.

What TEPCO learned from this accident is quite important to judge the level of resilience after the accident. As stated earlier, we have to admit that the long-term resilience of TEPCO had degraded gradually and the sensitivity for distance to the safety edge was not high enough to prevent the disaster. When we consider the possibilities of an operation of nuclear power plant in the future, the one of the essential characteristics of resilience, that is, learning capability of TEPCO should be evaluated cautiously. TEPCO already took actions to prepare hardware to prevent similar accident to happen. Furthermore, they established "Nuclear Reform Special Task Force" led by their president in order to reform TEPCO's safety culture, safety measures, disaster prevention measures, risk/crisis control protocol, information disclosure, and risk communication methods. The important point here is that they sincerely admitted that the accident is attributable to their lack of proper risk perception and also to the overconfidence in their safety culture. Authors believe that TEPCO learned much from this disastrous accident and they will continue to make efforts for enhancing safety and to maintain higher level of resilience in the future.

## **REFERENCES**

Hollnagel, E. & Fujita, Y. (2013). The Fukushima Disaster – Systemic Failures as the Lack of Resilience, *Nuclear Engineering and Technology*, Vol.45, No.1, 13-20.

ICAFNP-TEPCO (Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of Tokyo Electric Power Company), (2012)

<http://www.cas.go.jp/jp/seisaku/icanps/eng/final-report.html>.

IICFNA (The Independent Investigation Commission on the Fukushima Nuclear Accident), (2011), <http://rebuildjpn.org/en/fukushima/report/>.

Kadoma, R. (2012), Shinofuchi wo Mitaotoko (in Japanese), PHP INTERFACE.

NAIIC (National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission), (2012), <http://warp.da.ndl.go.jp/info:ndljp/pid/3856371/naiic.go.jp/en/>

TEPCO, (2012), Fukushima Nuclear Accidents Investigation Report  
[http://www.tepco.co.jp/en/press/corp-com/release/2012/1205638\\_1870.html](http://www.tepco.co.jp/en/press/corp-com/release/2012/1205638_1870.html)

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