Incident Recurrences in Nuclear Power Systems and Transparency of Root Cause Analysis: Block Chain based Safety Information Sharing

Minji Park* and Il Soon Hwang
Department of Energy Systems Engineering, Seoul National University, 31-1, One Gwanakro, Gwanakg. ,Seoul, 08826, Republic of Korea
**Corresponding author: minjipark@snu.ac.kr*

1. Introduction

1.1 Public-confidence in Korean Nuclear Safety Regulations

Surveys showed that Koreans demonstrate low public-confidence in nuclear safety regulations, which could be reasoned below.

In 2016, Korea Nuclear Policy Society [1] conducted survey on nuclear area residents. It demonstrates that 18% and 67% residents regard the nuclear plant is 'extremely unstable' and 'unstable', accordingly. 68% residents supported strengthening of local assembly members' responses and authority. 59% residents agree that an independent surveillance party including residents and experts are needed.

Comparing Korea, France and America's public interest was done by using Google Trend®. Indications of general public's interest in nuclear energy in the last five years (2013-2018) were surveyed. 'Safety', 'security', 'export' and 'spent fuel' were chosen as keywords and results are summarized in the Table 1. The keyword searches were limited to nuclear-related.

Table 1. Survey of public interest in nuclear safety, security, export, and spent fuel in ROK, America, and France (2018.01.26) as surveyed by Google Trend®

		2013	2014	2015	2016	2017
Safety	안전	727	660	708	416	784
	Safety	302	335	333	253	239
	Surete	405	634	497	512	430
Security	안보	0	0	0	0	0
	Security	163	181	178	236	174
	Securite	493	569	475	694	594
Export	수출	444	122	285	262	233
	Export	9	11	6	18	19
	Exportation	10	30	38	64	54
Spent fuel	사용후핵연료	44	0	70	31	29
	Spent fuel	1664	1777	1633	1558	1679
	Dechets	1788	2059	1958	1938	1751

'Safety' was the most interested keyword that Google Trend® count showed. Search interest for 'security' was not enough for the data to be shown, therefore indicated as 0, in case of ROK. [2] 'Spent fuel' was the major issue for American and French citizens. 'Safety' was listed second for American citizens. 'Safety' and 'security' were similarly popular as second interest, for French. [3]

In response to the distrust from the general public, the Korean nuclear regulator is also focusing its attention in this sector. With the 2nd Nuclear Safety Comprehensive Plan (2017 ~ 2021) by Nuclear Safety Commission, a proposal is submitted on the Introduction of a Comprehensive Analysis and Evaluation System for Safe Operation of Nuclear Power Plants. As one of key elements, Root Cause Analysis (RCA) strengthening is included. The purpose is to conduct trend analysis based on accident/breakdown history and to identify common causes and vulnerabilities, and to implement preemptive corrective actions. This would be done by promoting necessary legislation and related procedures/guidelines. Currently, there is no specific inspection activity related to RCA yet, but the requirement of individual process (case report, etc.) are gathered. [4]

Considering RCA vitality and increasing interests from the public and the government, further study is required. The three goals of this research could be briefed as following: 1. exploring incident recurrence due to root causes, 2. Nuclear Safety Act reinforcement neccessity, 3. safety transparency with confidentiality using blockchain. This could allow improved safety transparency policy and further sterengthening public confidence.

1.2 Incident Recurrence

On March 11, 2011, there was a nuclear accident in Fukushima, Japan. This marks INES level 7 and is recorded in the worst nuclear incident. However, when we look at the inside of this accident, there is a fundamental structural problem of the Japanese nuclear power institution, and it can be confirmed that the incident recurred because this fundamental problem was not corrected. [5]

Japanese nuclear power agencies share a vertical corporate culture, and there is a tradition that, when an order is issued from the upper part, despite of uncertainty, the order has to be conducted. Up to magnitude 8.6 quakes have been recorded along the same coast where the plant is located in 2008, and there was an opinion that a preparation is needed for the future. At the same time, lack of water-tight ability in seawater pumps detected since June, 2008. But due to economic and political reasons, Tokyo Electric Power

Company (TEPCO) did not carry out basic needs such as preparing for an emergency response system procedure in case of an event. [6]

In 1999, Japan Nuclear Fuel Conversion Co. (JCO), had an INES level 4 accident. This accident is blamed for having the worst nuclear fuel facility accident. It had no agency or person responsible for the incident at the time of the incident. Instead, the problem remained concealed. Absence of accountable control towers and fault in instructions were the persistent fundamental problems in regulatory bodies which JCO and Fukushima accidents share. [7]

More recently in 2018, Japan suffered from several more nuclear accidents. This is caused by a common root cause, the lack of responsibility allocation. For example, in April, 20, 2017, necessary on-site remediation measures were not implemented at Hamaoka Power Station. Due to the inadequacy of the site measures with the involvement of several stakeholders, several accidents occurred. [8], [9] These were due to the fact that the responsibility dedication was lacking. Person-in-charge did not dare to alter current, yet evident problem that they were facing.

Recurring incidents was the primary cause of public distrust in Korea. Wolsong unit#1 suffered from heavy water leakage in 1984. However, this was not disclosed until 1988 when the incident repeated in the same unit. Both incident reports by KINS are available online database. Details of the incidents were not fully disseminated, and root cause analysis was not provided in those reports. As part of corrective actions for the 1984 case, specific short term actions were listed. For 1998, further education, double surveillance system, supplementing procedure were introduced. In 1994, the same incident recurred, with rating of INES level 2. Incident Report and Event Details by KINS have only one and ten pages' length respectively. Corrective actions included tightening of specific parts replacement cycle, strengthening maintenance of specific subjects, and improving emergency response measures of operators. However, the heavy water leakage indent appeared as a KINS report after two years delay. [10] Short term corrective actions did not prevent further incidents from recurring. This is due to the fact that the root causes were not identified and/or fixed.

As referred to the cases above, there are always some fundamental problems beyond the impact of recurring nuclear accidents. Especially for these mentioned cases, the lack of responsibility dedication was the root cause of underlying problem.

According to Heinrich's law, there are 300 precursors (no injury accidents), and after 29 minor injury, one major injury occurs. [11] We want the nuclear power plant safety precursors to be eliminated. In 2017 world's total net capacity of nuclear power in operation was 394 GWe, whereas the net capacity of nuclear plant that generated electricity was 352 GWe. [12] Nuclear electricity in OECD member states in 2017 accounts for 17.6% of all electricity generation. This is the second largest of all sources (combustible fuel accounted 58.7%). [13]

Therefore, as nuclear holds a major role in electricity generation, countermeasures to prevent precursors deserve significant efforts. Precursors are sufficient precautions, which acts as an alert before the accident happens. Fundamental countermeasures lie in root cause analysis and its prevention by remedial measure.

2. Safety Transparency Assurance by Blockchain

2.1 Nuclear Safety Act

In order to restore public trust on nuclear power safety, incident recurrence should be avoided through root cause analysis. As the root cause analysis usually takes a long period of time, the process often get faded out if not discontinued due to various reasons. Transparency of the root cause analysis process is important as it can greatly help the process completion and result in remedy implementations.

In Korea, policies in nuclear sector roughly falls into two laws 1) the 'Official Information Disclosure Act' (2004.01.29, the article fully amended on 2013.08.06) and 2) the 'Nuclear Safety Act' (2015.06.23). They both stipulate matters concerning the disclosure of nuclear information. The 'Official Information Disclosure Act' is a system for ensuring the right of people to know and inducing participation. This is possible by disclosing information and supporting institutions such as state agencies and local autonomous bodies to the public.

Since the outbreak of Fukushima accident, public interest in safety regulation has increased, and in order to allow easy access to the information and accountancy, the Korean government is trying to disclose information before a request, and disclose original documents. [14] The 'Nuclear Safety Act' enabled 'Operational Performance Information System' for Nuclear Power Plant (OPIS) provided by KINS.

On the other hand, the Government of France stipulates matters relating to the nuclear information disclosure system in the 'Laws on the Nuclear Transparency and Safety' (TSN law, 2006.06.13). Through TSN, the Nuclear Safety Authority (ASN) was established, which later supports Commission Locale d'Information (CLI). Under TSN, ASN need to disclose documents voluntarily if it is determined that there is a need, even if there were no disclosure request. Nuclear power companies disclose nuclear power reports and other information on their web and provide information on nuclear facilities to CLI, even though they are non-governmental. [15] For CLI, the minimum constitution of environmental activist 10%, the professional 10%, the labor union 10%, local assembly member 50% is required.

However, in case of Korea, the commission has to include at least 15% from academia, 5% from environmental activists, 5% of employee of NPP headquarter. Despite the fact that Nuclear-related companies operating and managing nuclear reactors, nuclear fuels, and wastes in Korea are mostly public institutions, the local engagement is somewhat weak.

The contributing factor to this phenomenon in France is that the ASN is obligated to disclose information such as the results of screening related to construction, operation licenses for nuclear facilities, and the results of tests on nuclear safety management. However, the above information may not be disclosed, if it may seriously undermine the national interests or cause a gain or a disadvantage to a specific person by means of real estate speculation.

On the contrary, ASN of France excels nuclear transparency, with TSN, in the sense that CLI may require the nuclear operator to disclose information. Accordingly, France will disclose the documents at the early stage of production, even when the document is in interim state, to the general public.

If the information disclosure is denied, follow up action will be specified. For instance, if the organization does not possess information at the time of request, they should direct the request to other organizations and/or seek alternative information acquisition methods.

If the request is denied due to the fact that the requesting information is too specific, ASN may ask back on their request purposes more in detail. Furthurmore, the French Government also shares nuclear information via on-line site, data.gour.fr, and provides a platform for voluntary file sharing among citizens. [16]

Korea is lacking a Regional Information Committee (RIC) corresponding to CLI of France and underlying laws. In this paper, it is assumed that RIC and according law exists, which is similar to France case, and be regarded as a party to be involved in information sharing.

2.2 Safety Transparency with Confidentiality Using Blockchain

Misunderstandings and suspicion of corruption is due to the fact that nuclear documents and related news are just shared between operators and regulators, and the information transaction is not open to the public.

Especially, the reports do not direct root cause of an incident to be related to the fundamental, structural problems that an operator possess. Instead, the person who was present during the incident are the subjects of blame.

With the lack of transparacy, actual root cause may not be eliminated, or dealt with, and operation of the system proceeds at the risk of recurrence. This deteriorates nuclear reliability and public trust.

Maintaining nuclear information security, and the confidentiality of information from the regulatory bodies can be assured by introducing blockchain. This may act as a cure for lack of responsibility dedication. The entire process must be oversighted by National Assembly if the successful implementation is to be assured, based on French precedents.

Transparency assurance: document modifiation, and document person-in-charge is tracked

Confidentiality assurance: private chain invloves only three parties in this case, in a closed network

Therefore, implementing blockchain on nuclear safety information dissemination has three assets: 1) to provide stakeholders transparent and qualified nuclear information, 2) to identify responses and urge corrective actions, and 3) have low implementation cost for nuclear knowledge management.

Blockchain consists of four main parts: 1) transaction 2) block (growing list of records) 3) chaining 4) distribution. Transaction occurs when authorization/data/finance transfer is done by two or several bodies. [18] A block is composed of block number, block hash(any function that can be used to map data of arbitrary size to data of a fixed size), block header (usually consisted of six information), transaction information, and other information. [19]

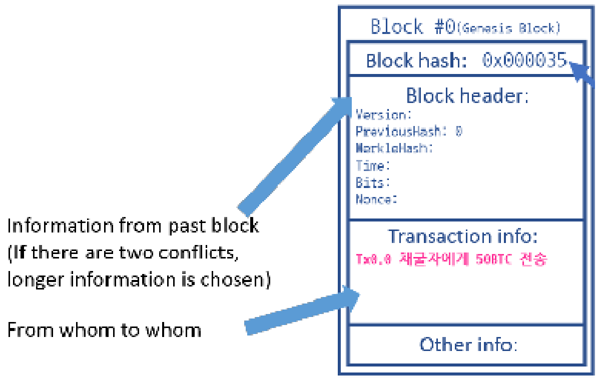

Figure 1. Standard block formation

In a block header, version is block version number, hashPrevBlock is 256-bit hash of the previous block header, hashMerkleRoot is 256-bit hash based on all of the transactions in the block, time is current timestamp as seconds since 1970-01-01T00:00 UTC, bits are current target in compact format, nonce is 32-bit number (starts at 0). First five information are all fixed, whereas nonce is not a fixed data. It is a random value, yet needs to fit certain criteria. The criteria is that the value of block hash needs to be smaller than certain value. Block hash value depends on version, previous hash, merkel hash, time, bits and nonce. Therefore nonce value is randomly put into generating block hash, and the nonce value which allows small block hash number will proceed. To sum up, nonce determines block hash and block hash allows a block's uniqueness. Therefore Nonce is the key for 'Proof of Work', in other words, generating an identifiable block. [20]

After a block is generated, linking block to block takes place, which is called chaining. If branch in the block chain undergoes collision, 'more Proofs of Work performed' blocks (longer length) become selected. Blocks proceed to link each other, and node is created. This is propagation via blockchain, distortion of information is made impossible due to the fact that all information are linked, and distortion is only viable when fundamental information is modified and therefore whole chain and the newly born blocks are all modified.

2.3 Potential implementation into Korea RIC system

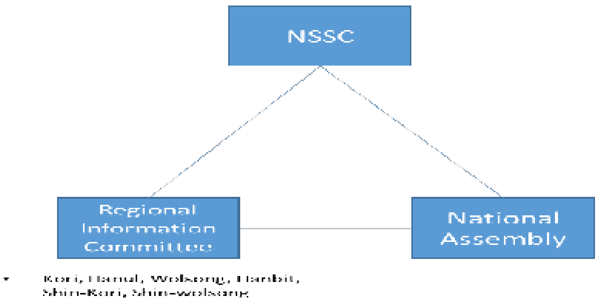

Figure 2. Illustrative organization involvement including NSSC, RIC, NA

Here, a private blockchain for inter-organization communication between RIC, NA and NSSC are suggested. This will ensure quick, transparent, tracked communicating ecosystem.

For each RIC, regional acts supported by Korea Hydro and Nuclar Power (KHNP), Korea Institute of Nuclear Safety (KINS), Nuclear Safety And Security Commission (NSSC), and the ministry of trade industry and energy(MOTIE).

Documents such as inventory change report, material balance report, physical inventory listing, concise notes, blueprint, corrective action request, incident reports will be shared voluntarily by NSSC, with encryption. The files contain black margins for confidential, specific parts. Any organizations which are willing to view the file must request a key to open the file. This way, the original file holder knows when and who accessed the file. This way, RIC may view the database list, easily visualize the overview, request a file of interest, and recieve it quickly. NA will act as a watchdog that NSSC is uploading all relevant information. NSSC may transfer files in a more secure environment. Along with uploaded files, metadata gathering will be done, which will provide an exploration line to categorizing nuclear information, which is desperately needed for nuclear knowledge management sector.

For metadata gathering, the documents relating to incidents will be mendatory. Along with these documents, metadata covering Title (Alternative), Creator (Contributor, Creator, Publisher, Rights Holder), Description (Table Of Contents, Abstract), Date (Created, Valid, Available, Issued, Modified, Date Copyrighted, Date Submitted, Date Accepted), Format (Extent, Medium), Relation (Is Version Of, Has version, Is Replaced By, Requires, Is Part Of, Has Part, Is Format Of, Has Format, Replaces, Is Required By, References, Is Referenced By, Conforms To), Coverage (Spatial, Temporal), Rights (Access Rights, License), Type (Document, Picture, Audio, Video), Language (English, Korean), Subject will be gathered.

In each authorizer's computer from three organizations, blockchain is planted. For ensuring the time that an organization accessed the file, following step is required. 1. Encrypted file via ECDSA(Elliptic Curve Digital Signature Algorithm, cryptographic algorithm) is distributed by IPFS(InterPlanetary File System, method to share files via blockchain). This will update newly submitted files in each computer. 2. For decryption, a company (Y) must submit request to the original owner (X) of the document. 3. X provides key to the file access. 4. X updates another document, stating that Y requested key, therefore Y opened the document.

Files are shared with a single naming format, which is Document date and time_Related content_verX. Version A corresponds to the fact that file opening request submitted by one of the following organizations: NSSC, RIC, NA. Version B is for file opening done by all organizations: NSSC, RIC, NA.

2.4 Impact of Block Chain Applications on Root Cause Analysis

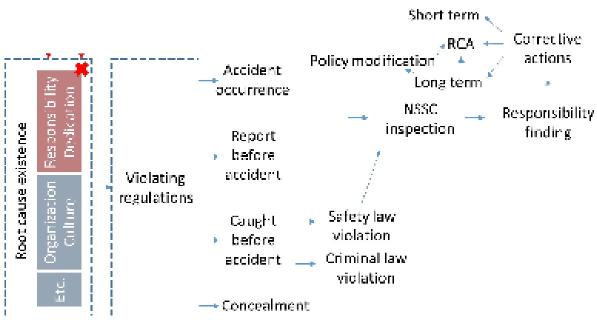

Figure 3. Root cause induced incident rerruring diagram loop with RCA as a cure

Among many other root causes, one discussed in this paper was lack of responsibility dedication. Through the appliance of blockchain, the regional watchdog can now access to files quickly, and wholly. Not only that, since the file transaction is all recorded in blockchain, altering uploaded files or its contents is not possible. RIC will act as a responsibility motivating group to NSSC, though continous surveilance and communication.

Once root cause vanishes, nuclear organizations will no longer violate regulations, which have been inducing incidents, reports, or concealments. Root cause eliminating could be classified as one of long term corrective actions in regards to incident responding.

3. Conclusion

Applying blockchain in nuclear sector is a pioneering work, at this stage, we tried involving only NSSC, RIC, and NA. This would open up a faster and comprehensive platform to share nuclear information between three organizations. Since it is a closed network, security is more assured. Most importantly, this will act as a triggering point to involve many other nuclear parties, which is a gate to many other benefits.

For instance, this theme could be elaborated more to involve all information exchanges between NSSC, KINS, KHNP, KAERI, RIC, and NA. Files that RIC have no authorization is uploaded is not problematic, because they are not able to view files anyways, without the original file sender's approval. Elaborating this theme will have even greater asset to the nuclear sector. First, information management will become more transparent and easy. This is possible by confirming the delivery of the document and the delivery process, and verifying the authenticity of the document. Second, root cause analysis and problem inducing point finding will become easier. This is due to the fact that seeking correlation between the document's certain characteristic and the responsive organization is possible with metadata.

Blockchain is a hot potato all over the world. Especially Korea, the government announced a "Block Chain Technology Development Strategy" plan up to 2022. For year 2018, among many other topics, the government is supporting distribution of electronic documents between countries via blockchain. Commercially, medical information, content copyrights are in exploration. As a consequence, blockchain based organizations are developing more efficient and fast algorithms, such as SPoR or Proof of Forkability, hyper dPoS, and aim for higher security such as through double secure network.

At the same time, NSSC announced the 2nd Nuclear Safety Comprehensive Plan for 2017-2021. This plan covers introducing a comprehensive analysis and evaluation system for safe operation of nuclear power plants, involving root cause analysis.

The subjects dealt in this paper are issues of attention, and further researches in developing from various sides of the world. With these attributions, nuclear transparency could skyrocket in the near future.

REFERENCES

[1] Society, K. N. (2016). Final Report On Restoring Nuclear Inspection Credibility and Public Participation.
[2] Google Trend [Online]. - 01 26, 2018. - https://trends.google.com/trends/explore?date=today%205-y&geo=KR&q=%2Fm%2F05k97.
[3] Google Trend [Online]. - 01 26, 2018. - https://trends.google.com/trends/explore?cat=954&date=today%205-y&geo=FR&q=s%C3%BBret%C3%A9,S%C3%A9curit%C3%A9,exportation,d%C3%A9chets.
[4] KHNP-CRI. (2018, Spring, Vol. 26). RCA Regulation Status.
[5] Robert Perkins [Online] // Fukushima disaster was preventable, new study finds. - 09 21, 2015. - 08 23, 2018. - https://news.usc.edu/86362/fukushima-disaster-was-preventable-new-study-finds/.
[6] Nuclear Regulation Authority Japan [Online]. - 08 23, 2018. - http://www.nsr.go.jp/english/index.html.
[7] Organizational Safety Culture for a Safer Society: Concepts and Implementations in nuclear power plant [Book] / auth. Oh Yongmin. - [s.l.] : Book Korea, 2014.
[8] NUCIA [Online]. - 08 23, 2018. - http://www.nucia.jp/nucia/kn/KnTop.do.
[9] FEPC [Online]. - 08 23, 2018. - http://www.fepc.or.jp/nuclear/safety/past/tokyodenryoku/index.html.
[10] This Is Not First Time (2012, 03 14). Retrieved from Pressian: http://www.pressian.com/news/article.html?no=106127
[11] Insurence, T. M. (2017, 05 15). Retrieved from http://transitmutual.com/TransitMutual/media/Docs/Accident%20Reporting%20Docs/Tip-05-15-17-300-29-1.pdf
[12]World Nuclear Performance Report 2018 [Online] // World Nuclear Association. - 08 23, 2018. - http://world-nuclear.org/getmedia/b392d1cd-f7d2-4d54-9355-9a65f71a3419/world-nuclear-performance-report-2017.pdf.aspx.
[13] Electricity Trends [Online] // IEA. - 08 23, 2018. - https://www.iea.org/newsroom/news/2018/april/key-electricity-trends-2017.html.
[14] World Nuclear Power Market Insight [Online] // Korea Energy Economics Institute. - 06 02, 2017. - http://www.keei.re.kr/keei/download/WNPMI170602.pdf. World Nuclear Power Market Insight [Report] / auth. institute Korea energy economics. - 2017.
[15] Nuclear Legislation in OECD and NEA Countries: FRANCE [Online] // OECD/NEA. - 2011. - https://www.oecd-nea.org/law/legislation/france.pdf.
[16] World Nuclear Power Market Insight [Online] // Korea Energy Economics Institute. - 06 02, 2017. - http://www.keei.re.kr/keei/download/WNPMI170602.pdf. World Nuclear Power Market Insight [Report] / auth. institute Korea energy economics. – 2017.
[17] Rediscovery of the Fourth Industrial Revolution: Blockchains and Codecs [Report] / auth. Joungho Kim. - Daejeon : TeraByte Interconnection and Package Laboratory, 2018.
[18] LG CNS Meets Blockchain Expert [Online]. - 08 23, 2018. – http://blog.lgcns.com/979.
[19] Wikipedia [Online]. - 08 19, 2018. - https://en.wikipedia.org/wiki/Hash_function#/media/File:Hash_table_4_1_1_0_0_1_0_LL.svg.
[20] Understanding Blockchain [Online]. - 08 19, 2018. - https://homoefficio.github.io/2017/11/19/%EB%B8%94%EB%A1%9D%EC%B2%B4%EC%9D%B8-%ED%95%9C-%EB%B2%88%EC%97%90-%EC%9D%B4%ED%95%B4%ED%95%98%EA%B8%B0.