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NEQM (NFC Based Equipment Qualification Management) System Preventing Counterfeit and Fraudulent Item

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Abstract: Qualification of equipment essential to safety in NPPs (nuclear power plants) ensures its capability to perform designated safety functions on demand under postulated service conditions. However, a number of incidents identified by the NRC (Nuclear Regulatory Commission) since 1980s catalysed the US nuclear industry to adopt standard precautions to guard against counterfeit items. The purpose of this paper is to suggest the NFC (near field communication) based equipment qualification management system preventing counterfeit and fraudulent items. The NEQM (NFC based equipment qualification management) system works with the support of legacy systems such as PMS (procurement management system) and FMS (facility management system).

Key words: Counterfeit items, fraudulent items, equipment qualification, NFC.

1. Introduction

The universally recognized methods used to establish EQ (equipment qualification) are testing, analysis, operating experience or an appropriate combination of these three methods. The EQ process consists of three phases: design input, establishing qualification and preserving qualification. The NFC (near field communication) technology makes a connection between the virtual world of the internet and physical world where we live. By doing so, through the full process of EQ, all stakeholders can share the EQ input data and performance data in real time. Therefore, introducing of counterfeit or fraudulent items to the safety related systems is prevented by proposed technology during EQ process. It is the key function of the NFC based equipment qualification management system. Of course, it is also possible to apply this technology to the non-safety related systems.

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2. Recent Counterfeit and Fraudulent Item Issues

Even though significant resources are at work addressing the issue of counterfeits from legal and enforcement perspectives, the number of counterfeiters is rapidly increasing. The rapid spread of manufacturing technology enables quick and easy creation of counterfeit products that are difficult to distinguish from the genuine product [1, 2].

2.1 Impacting US NPP (Nuclear Power Plant) between 2007 and 2009

The commercial nuclear power industry's quality assurance and equipment reliability programs have been successful in preventing counterfeit and fraudulent items from being installed in safety-related applications. However, there are several known incidents of counterfeit and fraudulent items that have been discovered in non-safety related inventory and even installed in non-safety related applications. The impacts on US nuclear power plants between 2007 and 2009 are as follows [1]:

(1) counterfeit ladish valves installed in non-safety related systems and stocked in several plants;

(2) incorrectly identified Flowserve valves;

(3) counterfeit electrolytic capacitors identified during receipt inspection;

(4) counterfeit integrated circuit installed in a portal monitor identified when the monitor failed calibration attempts;

(5) suspected counterfeit square D breakers in stock at several plants;

(6) counterfeit globe fire sprinklers with fraudulent UL (Underwriters Laboratory), incorporated label.

2.2 Examples of Counterfeit and Fraudulent Items Supplied to Nuclear Power Plants in Korea

All parts supplied for use in the reactors require quality and safety certificates from testing companies. Nevertheless, it turned out that, 587 parts in 34 categories used for nuclear reactors including Hanwool (Uljin) 3, 4 and Hanbit (Younggwang) 3, 4, 5, 6 were supplied based on forged qualification documents. Further inspection after the parade of shutdowns found 694 more parts in 12 categories with fake warranties used in Hanbit 5 and 6 to put off their reactivation [3, 4].

The details of crime will be turned out after the prosecutor's investigating is finished. In the meantime, the corruption cases can be classified into as followings according to the report of mass media:

(1) contract with an unlicensed contractor;

(2) pass the counterfeit item during acceptance test;

(3) supply fraudulent item to meet supply schedule;

(4) instigate fraudulent item because qualification process costs too much and requires too much time.

3. Equipment Qualification Concept

3.1 Basic Concepts for Equipment Qualification

IAEA (International Atomic Energy Agency) safety standard series No.SSR-2/1, Safety of Nuclear Power Plant [5] states:

"A qualification program for items important to safety shall be implemented to verify that items important to safety at a nuclear power plant are capable of performing their intended functions when necessary, and in the prevailing environmental conditions, throughout their design life, with due account taken of plant conditions during maintenance and testing."

IEC (International Electrotechnical Commission)-60780 as guidance for the qualification of electrical equipment states:

"This (qualification) program shall include qualification prior to initial equipment installation and subsequent requalification or replacement during the life of the plant as appropriate to demonstrate continuous fulfillment of performance requirements.

The methods of qualification are:

(1) performance of a type test on equipment representative of that to be supplied;

(2) performance of an actual test on the supplied equipment;

(3) application of pertinent past experience in similar applications;

(4) analysis based on reasonable engineering extrapolation of test data or operating experience under pertinent conditions.

The foregoing methods of qualification shall be used in combination as necessary...."

Assurance that safety equipment will perform when required throughout the equipment's installed life is provided by EQ and supporting activities ensuring that, the qualification conclusions continue to be applied to installed safety equipment. EQ is defined as the generation and maintenance of evidence to ensure that, safety equipment will operate on demand to meet safety system performance requirements [6].

3.2 PIEs (Postulated Initiating Events)

EQ should be established for the service conditions, including both normal operation and an appropriate set of PIEs [5, 7]. If the plant and its safety equipment can perform required safety functions while exposed to the effects of these PIEs, then it is assumed that, other similar but less severe events can also be accommodated. The most severe of the PIEs are termed DBAs (design basis accidents). PIEs include events expected to occur occasionally (e.g., loss of off-site electrical power) and others which ought not to occur but are theoretically possible, such as a large break LOCA (loss of coolant accident).

3.3 Selecting Appropriate Qualification Methods

Test, analysis, operating experience and combinations of these methods may be applied in a variety of ways to establish qualification. Type testing, as the principal qualification method, is the technically preferred method. Accordingly, this paper is focusing on the EQ process by type test. Type testing can rarely be applied to equipment without some analysis to address material, design, manufacturing or application differences between the tested and the installed items [8].

3.4 Seismic Qualification

As for the harsh conditions associated with LOCAs and HELBs (high energy line breaks), formalized qualification is generally required to establish equipment performance during seismic events [8]. The seismic qualification of equipment should demonstrate equipment's ability to perform its safety function during and after the time, it is subjected to the forces resulting from one SSE (safety shutdown earthquake). In addition, the equipment must withstand the effects of a number of OBE (operation base earthquake) prior to the application of an SSE. The most commonly used methods for seismic qualification are grouped into four general categories that:

(1) predict the equipment's performance by analysis;

(2) test the equipment under simulated seismic conditions;

(3) qualify the equipment by a combination of test and analysis;

(4) qualify the equipment through the use of experience data.

The choice should be based on the practicality of the method for the type, size, shape and complexity of the equipment configuration, whether the safety function can be assessed in terms of operability or structural integrity alone, and the reliability of the conclusions. Equipment being qualified must demonstrate that, it can perform its safety function during and after an earthquake. The required safety function depends not only on the equipment itself but also on the system and plant in which it is intended to function [9].

3.5 QA (Quality Assurance)

Appropriate QA measures should be applied to activities affecting qualification. These activities include, but are not limited to, equipment design, procurement, qualification, production quality control, application engineering, shipping, storage, installation, maintenance and periodic testing. The various types of organization and personnel performing EQ related activities include equipment manufacturers; material and parts suppliers; testing laboratories; EQ and equipment engineers; safety systems analysts; and equipment installation, operation and maintenance personnel [8].

3.6 Documentation and EQ File

Documented evidence of qualification needs to be available in an auditable form for the life of the plant. These records need to be organized in an understandable and traceable manner. The records need to be in a form allowing verification by competent personnel other than those establishing the qualification. The course of reasoning has to show that, the result is a consequence of the available assumptions and data.

When EQ is established under a formal

qualification program, most countries require the information used to establish qualification to be contained in, or referenced by, an EQ file. In many countries, each utility is responsible for establishing and maintaining an NPP site specific EQ file. In other countries, such as France, an EQ file applicable to various NPPs is maintained in a central location. The EQ file contents will vary according to the specific methods used to establish qualification. The file records should include:

(1) relevant details of the qualified equipment;

(2) qualification (test, analysis and operating experience) data;

(3) how the qualification data are synthesized to establish qualification;

(4) similarity between the qualified equipment and installed equipment and spare parts.

These documents are the basis for controlling the qualification established. The documents may be in paper or electronic format. Producing these documents, typically, requires a QA plan and procedures for review, approval and issuing of documents. In addition, retention periods of documents should be established. Where databases form part of the documentation process, ownership and change control of the databases should also be established [4].

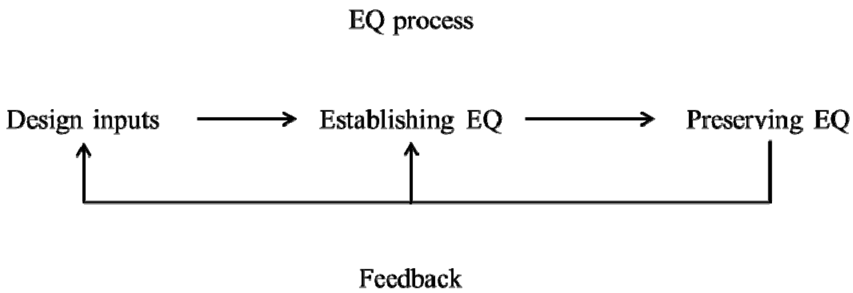
4. Current Equipment Qualification Process and Problems

4.1 EQ Process

The EQ process consists of three phases: design input, establishing qualification and preserving qualification. These three phases and the relationship of activities within each phase are illustrated in Fig. 1.

The information needed before EQ can be established for specific plant applications is provided in the design input phase. That information is developed by evaluating plant safety analysis, plant and system design criteria, operating and emergency procedures and equipment designs.

The establishing EQ phase involves all activities necessary to establish as shown in Fig. 1. If any, EQ critical equipment installation, operation, maintenance, replacement or modification activities should be identified. If plant modifications are required in order to establish EQ they also should be identified.



Design Input
- identify PIEs;
- specify service conditions;
- determine required safety functions;
- developing list of equipment, including functions and mission time.

Establishing EQ
- define EQ requirements and criteria;
- select qualification method;
- establish qualification;
- assess ageing effects;
- define installation and maintenance requirements;
- document qualification results.

Preserving EQ
- installation and maintenance control;
- replace control;
- modification control;
- service condition monitoring;
- analysis of degradation and failures;
- analysis of experience feedback;
- personal training;
- documentation.

Upgrading EQ

Upgrading EQ is a special case of establishing EQ that applies to existing equipment in operating plants.
Upgrading EQ may also involve establishing or verifying design input information.

Fig. 1 EQ process.

To reflect the requirements and limitations identified when EQ was established, a number of NPP activities have to be implemented and controlled that, throughout the NPP lifetime each installed item of equipment, after EQ is established. It is the preserving EQ phase. The preserving EQ phase involves equipment installation and maintenance, replacement equipment and spare parts procurement, plant and equipment modifications, monitoring of equipment condition and so on.

4.2 Problems Raised in the EQ Process

As mentioned in the Sections 2.6 and 3.1, many documents are developed and controlled during EQ process. The essential elements of equipment qualification include the followings:

(1) equipment specification including definition of the safety function(s);

(2) acceptance criteria;

(3) description of the service conditions, including applicable design basis events and their duration;

(4) qualification program plan;

(5) implementation of the plan;

(6) documentation demonstrating successful qualification, including maintenance activities required to maintain qualification.

Plant owner requests to A/E (architect engineering) company to prepare EQ requirements with equipment specification (Fig. 2). Equipment supplier prepares Qualification Program Plan according to the equipment specification. A Qualification Program Plan shall define tests, inspections, performance evaluation, acceptance criteria and required analysis to demonstrate that, when called upon, the equipment can perform its specified safety function(s). The required elements of the program plan shall include aging, qualified life objective, margin, maintenance, acceptance criteria as a minimum.

Upon the approval of the Qualification Program Plan by A/E, suppler sends the equipment to be qualified to the authorized test agency with the

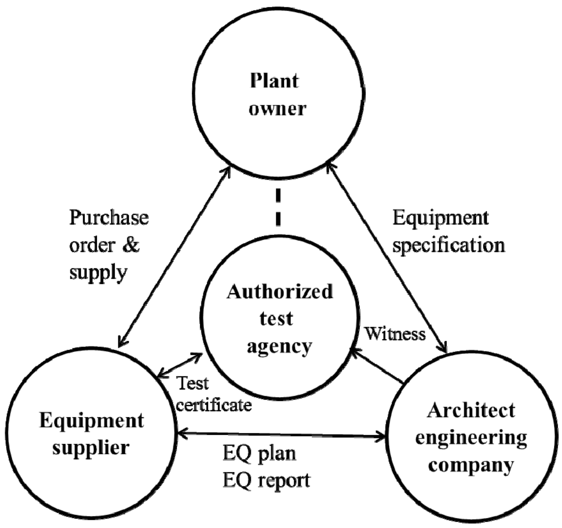


Fig. 2 EQ organization and functions.

Qualification Program Plan. Type test must be conducted in the test agency according to the Qualification Program Plan in the presence of a witness. The result of a qualification program shall be documented to demonstrate the equipment's ability to perform its safety function(s) during its qualified life and applicable design basis events. The documentation shall allow verification by competent personnel, other than the qualifier, that the equipment is qualified.

The problem recently raised in the EQ process is forged certificate. According to the KHNP (Korea Hydro and Nuclear Power), a control cable supplier manipulated a failed qualification test certificate and submitted to the KHNP. There were many similar cases in the test certificate other than qualification test. That means, even though there were well organized surveillance system, false test certificate was accepted without filtration during the EQ process. This is the reason why real time equipment qualification management system is necessary. Through the system every stakeholder can retrieve equipment qualification document in the same time by on-line. If then, test certificate is transmitted to the suppler and owner in the same time and manipulation of the certificate is protected.

On the other hand, due to the long term design and construction period of nuclear power plant, achieving consistency among design requirements, physical configuration, plant operation, and facility/equipment documentation is not easy. For example, when initial documentation is transferred from the original designer to the equipment supplier or plant owner, some of the necessary engineering files (justifications, calculations, consistency studies) may not have been established or provided, or may not have been up-dated according to the actual design at the test stage [10].

NFC based equipment qualification management system ensure that, the manufacture, fabrication and testing of the equipment is in accordance with the design requirements as expressed in the EQ documentation. An important objective of the NEQM (NFC based equipment qualification management) system is to ensure that accurate information, consistent with the equipment design, manufacture and test requirement, are available, in a timely manner to prevent counterfeit and fraudulent item.

5. NFC Technology for Real Time Two Way Communication

RFID (radio frequency identification) technology includes many standards that operate at LF (low frequency), HF (high frequency), and UHF (ultrahigh frequencies). However, many standards are incompatible with each other within each of these frequency domains.

QR (quick response) codes and RFID technologies have been widely explored to enable the connection between the virtual world of the internet and physical world we live in. QR codes can be printed at virtually no cost on existing packaging or the pages of a book, but might be considered too conspicuous and unattractive to marketers. In addition, QR code readers are sensitive to reader (usually a smartphone) orientation, and ambient lighting conditions and dirt, sometimes resulting in a difficult capture experience [11]. In the other hand, RFID systems are often more expensive than barcode systems.

NFC is a subset of these standards operating in the HF band at 13.56 MHz under the ISO (International Standard Organization) 14443, ISO 18092, and FeliCa standards, supporting a maximum data rate of 424 kbits per second (kbps) up to 10 cm (Table 1). The NFC protocol not only supports communication between an active reader and a passive tag, but also allows for peer-to-peer communication between two active readers. Thus, an NFC-enabled mobile phone can both read a tag and receive and transmit data to another NFC- enabled mobile phone. Furthermore, tags can contain read/write memory, and today there are tag products with 4 kbytes of Flash [11, 12].

A NFC enabled mobile phone can thus write arbitrary data into a tag as long as it fits in the available memory. When reading such a tag, a mobile device will obtain both a tag's unique identifier and if requested, the corresponding data contents. To support secure writing access, an unformatted tag is initially writable by everyone, but it allows a client to set a security key on internal blocks of data (Fig. 3).

5.1 NFC Enabled Mobile Phones

NFC enabled mobile phone is made by adding SEs (secure elements) and NFC interface. The NFC

Table 1 Comparison between NFC and other Short Range Communication Technologies.

Description	NFC	Bluetooth	Zigbee	IrDa
Connection	P2P	P2P	Star, P2P	P2P
Chip price	Low	Normal	Low	Low
RFID compatibility	Possible	Impossible	Impossible	Impossible
Range	Up to 10 cm	Up to 10 m	10~20 m	Up to 10 m
Transmission Speed	106~848 kbps	~24 Mbps	~250 kbps	~4 Mbps
Set-up time	< 0.1 s	~6 s	-	~0.5 s

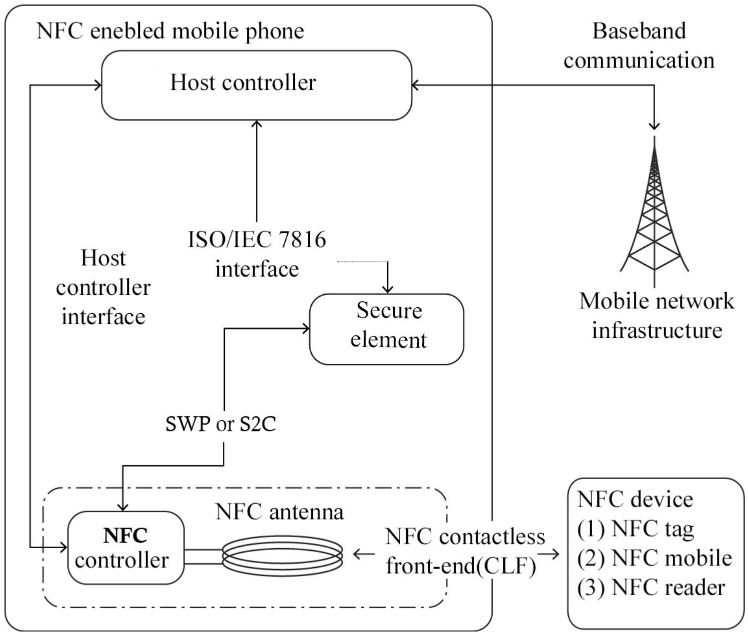


Fig. 3 Architecture of NFC enabled mobile phone.

interface is composed of a contactless, analog/digital front-end (NFC contactless frontend), an NFC antenna and an IC (integrated circuit) called an NFC controller to enable NFC transactions. For the secure proximity transactions with external NFC devices, at least one SE is connected to the NFC controller. The SE is necessary to provide secure environment for programs and data. The host controller (baseband controller) functions as the heart of mobile phone. The host controller sets the operating modes of the NFC controller through the HCI (host controller interface), processes data that are sent to and received, and establishes a connection between the NFC controller and the SE. In addition, it maintains the communication interfaces, peripherals and the user interface [13].

5.2 Operating Principles of ISO/IEC 14443

In the ISO/IEC 14443 protocol, proximity transactions are based on an electromagnetic coupling between a proximity card and RFID reader which uses an embedded microcontroller (including its own processor and one of several types of memory) and a magnetic loop antenna that operates at 13.56 MHz. ISO/IEEE 14443 enable contactless transactions between a reader device and a proximity card (or tag) used for identification. Contactless proximity smart cards operating at 13.56 MHz are powered by and communicate with the reader via inductive coupling of the reader antenna to the card antenna. An alternating magnetic field is produced by sinusoidal current flowing through the reader antenna loop. When a card enters the alternating magnetic field generated by a reader, an AC (alternating current) is induced in the card loop antenna. The data from the reader are clocked in, decoded, and processed by the IC embedded in the card. The IC communicates with the reader by modulating the load on the card antenna and the load on the reader antenna [13].

A NFC enabled mobile phone initiates the wireless communication, and can read and alter data stored in NFC tag. In this operating mode, a NFC enabled mobile phone is capable of reading NFC forum mandated tag type, such as NFC smart poster tags. This enables the mobile user to retrieve the data stored in the tag and take appropriate actions afterwards. NFC forum has standardized tag types, operation of tag types and data exchange format between components. The process consists of only reading data stored inside the passive tag and writing data to the passive tag.

6. NEQM System Preventing Counterfeit and Fraudulent Item

6.1 System Development

The system architecture can be seen in Fig. 4. It features two components: a NFC enabled mobile phone and a centralized web server. A dynamic interpretation of the operation of the system architecture of our implementation is presented in the interaction diagram in Fig. 5 [14].

The implementation allows the user to scan a passive NFC tag that has previously had an equipment identification written to it by a process that will be described later. Two APIs (application programming interfaces), namely JSR (Java specification request) 257 and JSR 177, are required to develop NFC application. JSR 257 provides reader/writer mode application programming resources, whereas JSR 177 and some classes in JSR 257 provide access to SEs.

As shown in Fig. 5, install NEQM server and NFC tag platform. Then, build a mobile web for the operation of the NEQM system. Attach a NFC tag to each equipment or device to be tested or qualified and embed an URL (uniform resource locator). Each tag has unique identification (URL). For the exchange of information between NEQM system and legacy system, for example, procurement management system or plant information system, interface system has to be developed.

6.2 Operation of the NEQM System

The NEQM system can be used in line with qualification test, factory acceptance test and site acceptance test. Inspector and witness touch the NFC tag attached at the equipment by NFC enabled mobile device such as smartphones. Then, equipment identification information is sent to the smartphone with the URL where the details of the qualification equipment and test procedure are stored. Inspector and witness can browse the technical specification, test procedure and acceptance criteria through the NFC enabled mobile phone to perform the equipment qualification test. NEQM server controls access to the equipment data and qualification information for the secure operation of the system. Inspector and witness start the inspection and test with the signing on the test report. Inspector and witness can accomplish the proof of presence through the real time data communication with NEQM server. After finishing test, inspector writes the test results on the test report

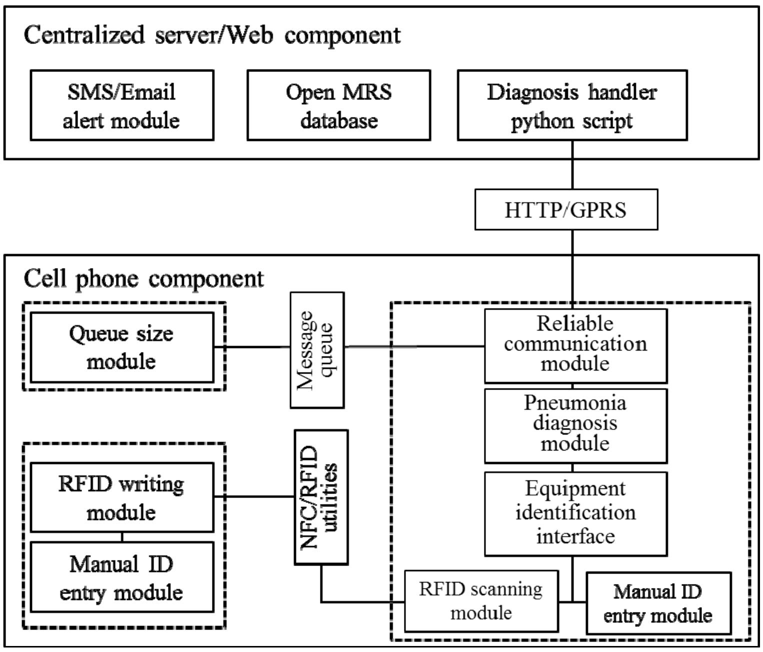


Fig. 4 NEQM system architecture.

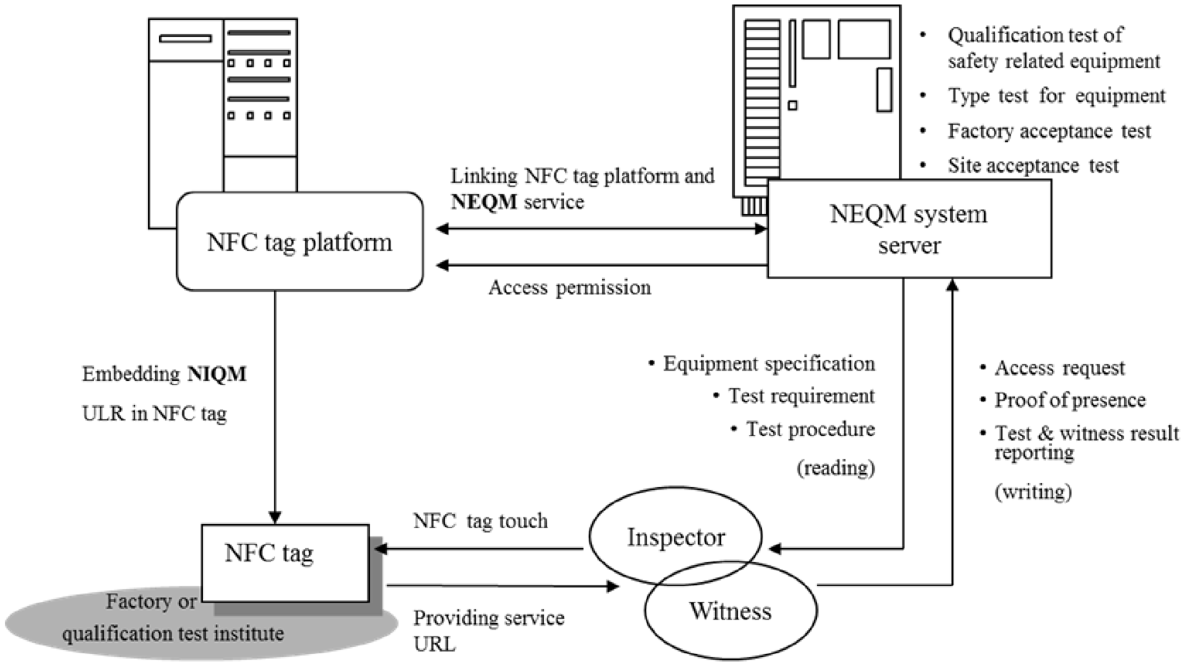


Fig. 5 NFC based equipment qualification management system.

format preloaded in the NEQM server. Then, witness cosigns on the test report. The test results are shared by manufacturer, test institute, third party witness and end user in real time base. Therefore, the NEQM system can prevent counterfeiting of the test report or certificate.

7. Integration of the NEQM System with Legacy System

An evaluation of past IRS (incident reporting system) data indicates that, a significant number of reported events have resulted from errors in the control and maintenance of the configuration of the physical facility, errors in the original design or design modifications, inadequate corrective actions, inadequate testing and documentation discrepancies. A review of results of IAEA OSART (operational safety assessment review team) missions and follow-up reports shows also that many findings are related to configuration management deficiencies [10]. Therefore, the IAEA has developed the guidance on configuration management for nuclear power stations.

NEQM system can be applied to the CM (configuration management) of nuclear power stations by integration with the legacy systems such as PMS (procurement management system), PCS (plant control system), and FMS (facility management system) as shown in Fig. 6.

A/E registers the key information of equipment such as ID (identification) number and technical specification on the ELMS (equipment lifecycle management system) in the design phase of a plant. Then, links other detail information stored in the PMS, PCS and FMS stage by stage. If the key information is revised, the ELMS notify to every systems linked with the ELMS. The ELMS helps to maintain the integrity and accuracy required of licensing documents, maintenance procedures and operating procedures.

8. Conclusions

This study has shown how to apply the NFC technology on the equipment qualification management to prevent counterfeit and fraudulent items. The NFC technology enables real time two way communication between NFC tag and NEQM system. And, EQ files are shared by every stakeholder through the mobile network and internet in real time.

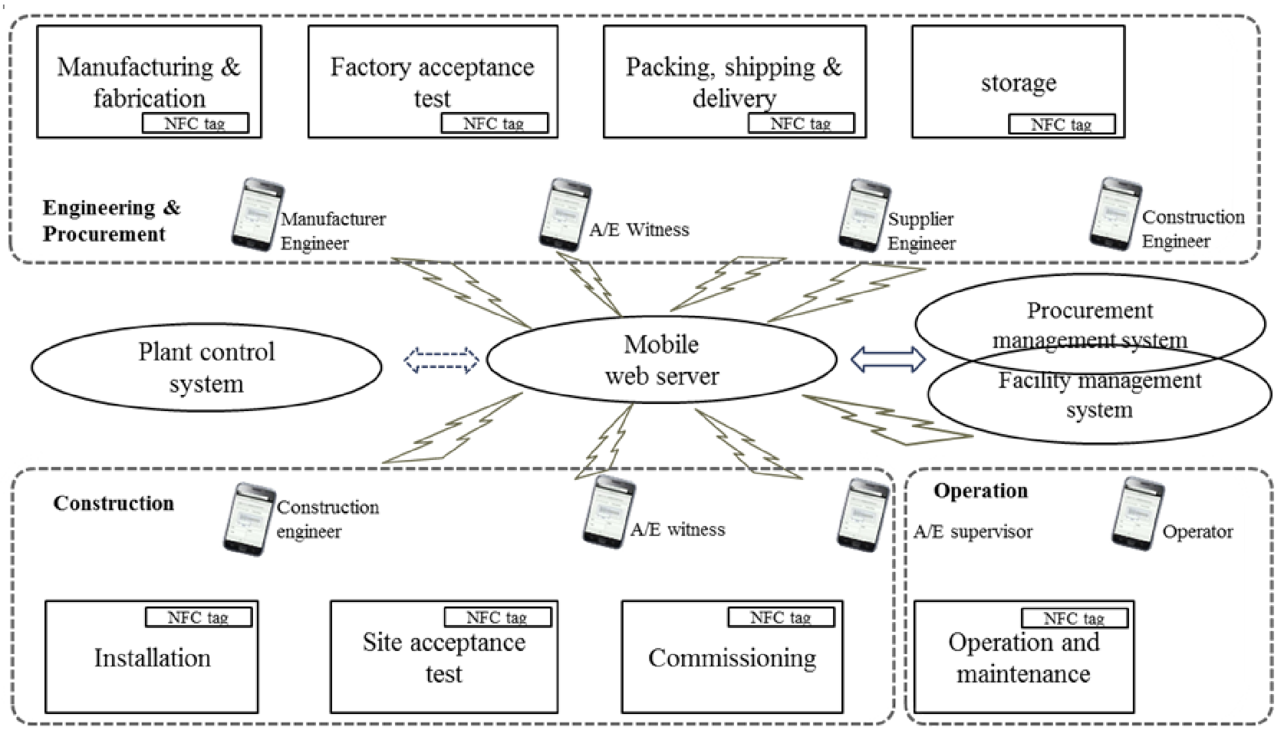


Fig. 6 NFC based ELMS.

Therefore, no counterfeiting or forging is allowed. Furthermore, NEQM system can be used as an ELMS if it is interfaced with legacy system.

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