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DEPLOYING INDUSTRIAL INTERNET OF THINGS (IIOT) IN NEWLY-BUILT NUCLEAR POWER PLANTS

Abstract

The Industrial Internet of Things (IIOT) evolution made IIOT deployable in nuclear power plants for remote access and monitoring operations. The deployment will be technically effective and economical when deployed during the construction of the NPP than on existing NPPs. Most existing NPPs were constructed prior to the digitalization era, so they do not provide the data visibility IOT needs to work. Deployment of IOT sensors at the design and construction stage will supply the operating system with raw data transmitted to the monitoring system for necessary predictions in real-time.

Index Terms

Industrial Internet of Things, Smart Nuclear Power Plan System, Safety and Security, Cyber Risks and Security

1. Introduction

The adoption of the Internet of Things (IOT) resulted in the rapid growth of connected objects in recent years. In the next 20yrs, there will be an estimated 30 billion IOT connections in the Universe, averaging to 4 devices per person [1]. IOTs are deployable in various applications such as Smart Houses, Smart Cities, Smart Health, and Smart Nuclear Power Plants.

2. Motivation and Contribution

IOT is an approach that links the internet with sensors and working devices for an all-internet protocol (IP) based architecture [2]. However, few research works are found in existing literature addressing the applications of IOT in newly built Nuclear Power Plants. This motivated research highlights the clear concept of the deployment of IOT in NPP operations and control systems for safety and security, the uniqueness of IOT as a solutions identifier, senses the physical phenomena of radiation and its effects, and wireless data communication and remote data management.

3. Internet of things and their application in NPPs

The internet offers a communication bridge between transceivers and users and acts as the next giant leap ahead in the information and communications technology (ICT) sectors [3]. IOT increases the efficiency of systems by enabling them to communicate in real-time. Thus delivers data and information for critical decisions faster than humans [4]. The key strength of IOT is the promotion and upgrading of intelligent environments by incorporating intelligent devices to communicate, process, analyze, store and manage data autonomously without the necessity for any human intervention.

Industrial Internet of things (IIOT) is a term used to refer to IOT principles when they are applied in an industrial environment, for example, in Nuclear Power Plants (NPPs). Data communicated in IIOT through smart machine parts such as pressure, temperature, flow rates, machines conditions, etc., is connected between two smart devices, between several devices, between devices and users or between users, at any given time [5].

3.1. Application of IIOT in Nuclear Power Plants

Nuclear Power Plants (NPPs) are sophisticated systems that are operated and maintained constantly with the highest level of safety and security. Regardless of their age, NPPs are monitored with the same optimum degree of attention to detect possible failure or its signs early in time to enable rapid intervention and prompt mediation [6]. NPPs are usually operated for an extended period of four to five decades with a provision for an extension of another decade or two, depending on the reactor design [7]. Data that could be communicated for safety and security purposes could be obtained by the deployment of IIOT in NPPs. For example, the Fukushima Nuclear Power plants disaster was partly attributed to the old monitoring system called SPEEDI, which failed to convey the necessary communication required for evacuation as it was deployed about 30 years ago [8]. The disaster could have been averted by deploying IOT equipped with smart sensors that will communicate real-time data for prompt decision-making, enhancing productivity in the nuclear sector, improving safety, and increasing productivity with lesser human input [9].

Deployment of IIOT in radiation monitoring will enhance efficiency, enable remote monitoring, reduce the duration and eliminate the need for ICRP regulations [10]. Furthermore, cost reduction is one of the essential aspects of business, especially in Power generation, where Nuclear energy aims to lower production costs compared to other cheaper alternative sources of energy.

3.2.1 Deployment of IIOT existing NPPs

Most of the existing NPPs have been constructed before the digitalization era and do not provide the data recognition IOT needs to work [11]. Deploying IIOT in older NPPs is a near-impossible task. Existing plants will require extensive mechanical and electrical engineering redesigning, cutting, drilling and running cables that could run up to hundreds of thousands of dollars, hardware-software compatibility testing, assessment, certification and extended shut-down of operations in the affected sections. It could also take years to execute, attracting a series of approvals from the Regulatory authority [12]. Consequently, safety is of the highest consideration for an innovative approach in maintaining or redesigning any Nuclear component. In addition, it must be ensured that the new technology does not affect the workers, environment, and general public. All requirements are monitored and enforced by the relevant authorities [13]. Therefore, the overall long-term assessment of the whole exercise could prove uneconomical.

3.2.2 Deployment of IIOT in newly built NPPs

Incorporating IOT technology at the design and construction stage in newly-built NPPs will prove advantageous and enhance productivity, safety and durability while ensuring the lowest operational downtime. A maintenance schedule will be optimized on a needed basis, which will extend the plant's life span and higher returns in invested resources. All software will be designed and engineered in perfect compatibility with the designed hardware, providing future upgrades. Thus, operators will have an added advantage of continuous operation since maintenance would be well scheduled at a minimal cost. Radiation monitoring could be done remotely, and data could be transmitted wirelessly.

Some benefits of IOT deployment during construction include:

a. Sensors could be embedded in in-situ concrete, drilled in solid concrete and metal components during fabrications and surface finishes. This would be beneficial and cost-efficient in monitoring machine performances and signs of deterioration in both steel and concrete structures

b. . During installation, fewer or no wires are needed for the wireless sensors, as some could be battery operated,

c. increased mobility and convenience through a wireless network that could be accessed from different locations within and outside the plant,

d. easier expansion of wireless network without additional equipment, unlike in wired connections where additional wiring is required,

e. the ability to move terminal, nodes and sensors around for relocation,

f. absence of signal and power cables will result in lesser installation and maintenance costs,

g. The possibilities of novel applications and operation methods were not earlier adopted in NPPs.

4. Challenges of deployment of IOT In NPPs and solutions

There have been a lot of scepticism, limitations, challenges and risks associated with the deployment of IOT in the nuclear sector. The most pronounced obstacles associated with IOT technology are Power limitations, Storage limitations and Cyber/Data Security challenges.

Power Limitations

Most IOT devices are low powered with limited service time, which may not meet the desired duration, especially when an additional security application operates. As a solution, an alternative power source is provided along with batteries that could last an entire maintenance cycle without replacement.

Storage limitations

IOT, as a connection of many devices, generates a large amount of data, which needs to be stored for processing and analysis. Therefore, cloud-based storage and servers with big data analytics are required, located outside the facility, thereby putting the data in a compromising position. However, company-specific cloud storage could be designed specifically for the IOT system offered to the operator, thus preventing the IOT wireless communication from exposure to the broader network.

Cyber/Data Security Challenges

Most wireless devices are prone to cyber threats, including various attack scenarios like unauthorized access, eavesdropping, interception, network jamming, and denial of access. Cyber and data security risks are addressed from the system design stage where comprehensive and effective mitigation techniques, strong encryption of transmitted data, authentication of access and detection of unauthorized transmission measures, etc., are all put into place.

5. Conclusion

Deployment of IOT in newly-built NPPs at the construction stage is something newcomer countries should adopt as the novel nuclear business strategy. Moreover, regulatory bodies and other standardization bodies have shown keen interest in IOT application in NPPs. It proves to be a new method to revolutionize the nuclear power business.

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