RUFORUM Working Document Series (ISSN 1607-9345), 2018, No. 17 (2): 127-130.
Available from http://repository.ruforum.org

Research Application Summary

Environment monitoring sensors for future nuclear power plants

Amitu, D.M. & Otto, F.

Regional Universities Forum for capacity Building in Agriculture (RUFORUM), P. O. Box, 16811, Wandegeya, Kampala, Uganda
Corresponding author: d.amitu@ruforum.org

Abstract

The next generation of nuclear power plants should not be limited to only detecting, locating, and identifying equipment faults but also smart and able to identify sensor degradation. For example, temperature sensors for new generation of nuclear power plants will progressively replace those currently in use because new power plants are required to operate at higher temperatures than the current generation (that is, with outlet temperature up to and beyond 1000^{o}C) to improve efficiency. The challenges posed by the higher temperature environments render the current temperature sensing technologies inadequate. In order to maintain the safety and reliability in the long-term for such plants it is essential that new environmental (temperature for example) measurement sensors and methods for in-situ measurement are investigated and developed. Therefore, future nuclear plants require a smart integrated approach for monitoring, control, fault detection and diagnosis of all plant components such as sensors, actuators, control devices and other equipment. In this paper some research challenges and recommendations are raised in the area of environment monitoring sensors for future nuclear power plants.

Key words: Condition monitoring, nuclear power plant, sensors

Résumé

La nouvelle génération de centrales nucléaires ne devrait pas se limiter à la seule détection, localisation et identification des défauts de l’équipement, mais aussi être intelligente et capable d’identifier la dégradation des capteurs. Par exemple, les capteurs de température de la nouvelle génération de centrales nucléaires remplaceront progressivement ceux qui sont actuellement utilisés, car les nouvelles centrales doivent fonctionner à des températures plus élevées que la génération actuelle (c’est-à-dire avec une température de sortie pouvant atteindre et dépasser 1000°C) pour améliorer leur efficacité. Les défis posés par les environnements à température plus élevée rendent les technologies actuelles de détection de la température inadéquates. Afin de maintenir la sécurité et la fiabilité à long terme de ces centrales, il est essentiel d’étudier et de développer de nouveaux capteurs environnementaux (de température par exemple) et de nouvelles méthodes de mesure in situ. Par conséquent, les nouvelles générations de centrales nucléaires nécessitent une approche intégrée intelligente pour la surveillance, le contrôle, la détection des défauts et le diagnostic de tous les composants de la centrale tels que les capteurs, les actionneurs, les dispositifs de contrôle et autres équipements. Dans ce document, certains défis et recommandations de recherche sont présentés dans le domaine des capteurs de surveillance de l’environnement pour les nouvelles générations de centrales nucléaires.

Mots clés : Surveillance de l’environnement, centrale nucléaire, capteurs

Introduction

Environment monitoring and timely detection of incipient faults are critical for operational safety and performance enhancement of nuclear power plants. In plant operations there can be various sources of anomalous behavior (i.e., deviation from the nominal condition), for example it could be the consequence of a fault in a single component or simultaneous faults in multiple components. Often it is difficult for the plant operator to detect the anomaly and locate the associated anomalous component(s), especially if the anomaly is small and evolves slowly. Upon occurrence of an anomalous event and subsequent perversion of its effects, the operator could be overwhelmed by the sheer volume of information, generated simultaneously from various sources.

Therefore, it would be beneficial to develop an automated environment monitoring system to assist the plant operator to detect the anomalies and isolate the anomalous components (Jin et al., 2011). Environment monitoring with sensors in nuclear power plants involves the automated assessment of the condition of the mechanical and electrical components of the plant hence it aids in the implementation of preventative maintenance. Preventative maintenance helps to predict when maintenance should be performed and offers a number of key benefits over more traditional strategies such as run-to-failure or scheduled maintenance. These involve the elimination of some in-service failures and unscheduled down-time, together with savings in costs, as maintenance tasks are only done when due or warranted and components are only replaced when faults are known to have developed. Further, the chances of secondary damage caused by in-service component failure is eliminated (Upadhyaya et al., 2003), (Bogue, 2013). This is so because a nuclear power plant tends to encounter harsh environmental conditions like very high temperature etc that give rise to age-related degradation of the plant structures (Chong et al., 2011). However, the implementation of preventive maintenance requires the installation of sensors in the critical areas of the nuclear power plant. These sensors could be wired or wireless but wireless sensors come with some challenges like cyber security, communication reliability, industry regulation, and electromagnetic compatibility (EMC) issues. Additionally, sensors health monitoring is essentially important for reliable functioning of safety critical chemical and nuclear power plants (Shaheryar et al., 2016). The main objective of this paper is to raise some of the potential challenges that need to be addressed by wireless sensor technology for seamless operation with the next generation nuclear power plants.

Challenges

Nuclear power industry is highly regulated thus slowing the implementation of wireless technologies like wireless sensors but with enormous advantages which come with it, the future Nuclear power plants are expected to fully embrace wireless technologies like wireless sensors for condition monitoring. Therefore, this paper points out some of the challenges which need to be addressed for the wireless technologies implementation in the next generation nuclear power plants for environmental monitoring. These include the following:

Communication reliability. Communication reliability is a concern due to intermittent obstructions to wireless communication paths from moving equipment (e.g., cranes, vehicles).

Cyber Security. Validity of measurements in the nuclear industry is important because a sensor failure can have serious consequences. Thus, it is essential to regularly ensure correct operation of sensors, in particular for those having great importance for operating safety, in order to locate and identify any possible degradations (Dorr et al., 1997). The primary means of data protection for wireless transmissions include encryption, authentication, and intrusion prevention.

Electromagnetic compatibility. Most nuclear power plants are prone to electromagnetic interference due to transmitter signals coupled with unplanned expansions of the nuclear plants. Therefore, with the guide for Electromagnetic Compatibility (EMC) for nuclear power plants it is possible to establish the safe locations of the transmitter relative to its power and distance from sensitive equipment.

Recommendations

This paper recommends the following:

(i) The use of mesh networks that offer additional or redundant paths for communication can reduce the likelihood that normal plant operation will interfere with the wireless transmission. Also, modern wireless networks are "self-healing", meaning that if a communication path is interrupted, the network devices will automatically identify another route to transmit the data until the original path is restored. In addition to network configurations, wireless communication signals are modulated, employ frequency hopping, and use standard protocols to reduce errors and maintain connection for increased communication reliability. The task here involves the design and development of robust routing algorithms for sensor communication in condition monitoring for future nuclear power plants.

(ii) For environmental monitoring applications such as those presented here, standard encryption and authentication is typically sufficient for protection of the wireless network. However, for future nuclear plants, advanced encryption and authentication methods should be developed to match with the evolving and sophisticated nature of cyber-attacks.

(iii) To develop an innovative and collaborative research that attempts to address future nuclear power plant challenges by exploring on key sensor technologies suitable for monitoring critical equipment and their surrounding environment.

(iv) To develop robust algorithms for sensors condition monitoring applications with ability to operate in harsh environments.

Conclusion

This paper has demonstrated how wireless technologies can play a key role in future nuclear power plants and therefore research on the development of an integrated wireless condition monitoring systems for future nuclear power plants is needed. The paper also raised issues that have delayed application of wireless monitoring in nuclear power plants including but not limited to: cyber security, electromagnetic and radio frequency interference, wireless network infrastructure and reliability. With reliability the paper emphasized that the validity of measurements in the nuclear industry is important because a sensor failure can have serious consequences. Thus, it is essential to regularly ensure the correct operation of sensors, in particular for those having great importance for operating safety, in order to locate and identify any possible degradations.

Acknowledgement

This paper is a contribution to the 2018 Sixth Africa Higher Education Week and RUFORUM Biennial Conference.

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