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Review report of a PhD thesis submitted
to the Faculty of Electrical Engineering of Gdynia Maritime University
entitled
"Analysis and Assessment of the Quality of Wireless Information Transmission on Shipboard Measurement and Control Systems – Collaborative Perspective"

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1. Introduction

The shipboard measurement/control systems play a very important role in the everyday operation of the ships. The wired and wireless systems are now used in shipbuilding engineering. The interest of shipyards and the ship owners is to lower the construction cost while keeping the good quality and reliability in different operational conditions of the ships. The problems with the wired systems applying 4-20 mA analog standard, where measuring points are remotely separated by long distances, are associated with cable properties and are induced by high changes of temperature, humidity, vibration, and salinity in everyday operations. Minimization of the cost of the ship forces to adapting the wireless technologies to cooperate with the cabling systems of classical standards. In this way the enhanced quality levels of the measurement/control process without the necessity for total replacement of cabling are achieved. The wired system performs the role of a cooperative medium and does not eliminate the wireless one.

The main goal of this PhD thesis is the analysis and assessment of the quality of wireless transmission systems used in shipboard measurement and control systems in collaboration with the existing wired classical solutions applied on the ships. As a result of such

considerations, the thesis introduces the recommended techniques to avoid some negative effects, like improper grounding techniques, vibration, high levels of humidity, and corrosion on the 4-20 mA HART smart sensing current loop, etc.

In my opinion, the aim of the thesis is well fit to the actual problems of ship measurement/control systems. The results obtained in the work lead to enhanced knowledge of the problems and their solution in the very specific maritime environments.

2. **Evaluation of the merits of the dissertation**

The PhD thesis text is rather long and contains 135 pages divided into four chapters, including the introduction, conclusions, and bibliography.

The first chapter is devoted to the wired shipboard measurement/control systems based on 4-20 mA analog standard. The instrumentation cables are used as the medium for data transmission. The HART (Highway Addressable Remote Transducer) and FF (Foundation Fieldbus) protocols for transmitting digital information between field devices and control systems are considered. Different problems of the degradation of the cable characteristics are pointed out. They are associated with the changing temperature and humidity, salt water presence, vibration, etc.

The author has developed the Simulink model to simulate the tank level measurement process on a commercial ship through pressure transmitters mounted at the bottom of the tank. The experiments have shown the negative effect induced on the 4-20 mA current loop by ground loops, common mode noise, and coupled noise. The other Simulink model was dedicated to the simulation of the process of modulation/demodulation of Manchester coded FF bus signal with the bit rate of 31.25 kbps in ideal and noisy conditions. The results of experiments have been presented and discussed.

The second chapter is devoted to the wireless HART protocol (HART 7.1 extension) used in maritime engineering. It introduces different elements of this protocol and discusses various aspects of its implementation on a few types of commercial ships (container, tanker, and bulk carrier). The important part of the chapter is the mathematical model developed to reinforce the wireless HART network in order to achieve the specific goals of the

designer. The model is directed to create a rectangle between the points of maximum and minimum of x and y coordinates at each quarter, where the field devices outside the gateway's effective range are located.

According to the resulting rectangles and the area of the repeater range circles, a specific number of repeaters will be installed inside each of these rectangles. The chapter presents the set of equations defining the model and shows the graphical results of the performed simulations. The last section of this chapter is devoted to the presentation of the system for the seawater level in ballast water tanks on bulk carriers. The results of the simulation are presented and discussed.

Chapter three is devoted to the Wireless Technologies (Wi-Fi) used in maritime engineering. The Wi-Fi is developed in a ship's environment as a data transmission medium in measurement and control systems as an alternative to more expensive wireless technologies, like HART. It is aimed to collect the measurement data from multiple 4-20 mA analogue transducers, to authenticate the reception of the transmitted data to the host controller, and to verify the measured data through the coexistence with the wireless HART protocol.

The chapter introduces the main elements of Wi-Fi technology (Arduino MEGA2560 controller, ESP32 controller, and Bullet wireless HART adapter). The ESP32-based Wi-Fi as a medium for measurement/control can be applied on small as well as large scales (one or multiple systems in the specific maritime engineering). The chapter shows the application of the ESP32-based Wi-Fi system on commercial container ships in order to identify the best location for the ESP32. The results are shown for large and small-scale applications. The experiments are well presented, and their results are discussed.

The chapter ends with a section devoted to the predictive maintenance application dedicated to monitoring the changes in the cargo crane hydraulic oil dynamic viscosity values. The developed mathematical model is dedicated to the analysis of the differences between the reference and the calculated values of the dynamic viscosity at specific working hours.

The chapter called “Discussion” has summarized the results presented in the previous chapters. It stressed different possibilities of enhancing the reliability and stability levels of maritime measurements and control systems based on the conventional techniques, adopting the classical binary/analogue standards. The results of numerical experiments using Simulink have shown various preventive measures that can be carried out to eliminate the effect of common mode noise as a couple noise in 4-20 mA measurement current loops in tank level measurements on a ship.

The important part of the thesis is concerned with the wireless technology (wireless Hart protocol and Wi-Fi) used as a medium for data processing in marine measurement and control systems. Based on the results of experiments author has proposed some recommendations for preferring the particular wireless solution: HART protocol or Wi-Fi. HART protocol is recommended to process only analog input signals from 4-20 mA analogue transmitters. In the case of signals coming from on-off binary switches, the Wi-Fi technology is recommended.

The last chapter, “Conclusions” is a continuation of the previous chapter and highlights the main achievements of this doctoral study. It stresses the validation of the strategy aimed at integrating the selected wireless technologies in the processing of the measured data obtained in conventional cabling systems. Thanks to such collaboration, it is possible to reduce the cost of the measurement/control system, as well as to minimize the probability of data processing failure and to facilitate the process of fault detection during troubleshooting. The main original achievements of the dissertation study include

- Analysis and comparison of the wired and wireless measurements/control systems in maritime engineering.
- Highlighting the effect of vibration and humidity on the 4-20 mA smart HART measurement current loop.
- Developing a new method to eliminate the effect of additive white Gaussian noise on the 31.25kbps FF H1 bus signal.
- Showing the advantages of collaboration between the conventional wired and the wireless systems.

- Performing many simulations of different systems, allowing us to propose some recommendations for the shipbuilding process.

The work is written clearly and in a good style. It concisely presents the most important elements of the analyzed systems, then illustrates the results of simulations using the Simulink models. The discussion of the results concerning the various issues raised in the thesis is appropriate and systematically carried out in each section of the dissertation.

The objectives of the work and the thesis have been well presented and documented in the content of the dissertation. In the concluding sections, the author has formulated the main research achievements presented in the dissertation. I agree with these statements. Taking all this into account, I would like to express my positive opinion of the dissertation.

3. Critical remarks

The dissertation under review belongs to the good doctoral theses. However, I have a few critical comments, most of which are of little importance and do not affect my high assessment of the dissertation in any way.

1) In my opinion, the text of the dissertation is too long. There are many repetitions, especially in the sections called “Discussion” and “Conclusions”. Both of them should be condensed into one chapter of much shorter length.
2) The set of mathematical equations in the chapter 2 (pages 53 -68) and chapter 3 (pages 112- 115) should be eliminated from the main text (they might be included in the form of appendix). Moreover, their theoretical introduction is far insufficient, hence difficult to understand and follow.
3) The graphical results presented in Figures 2.3 and 2.5 need better description and discussion in the text.
4) The bibliography list is rich; however, many positions from the list are not cited in the text.

4. Concluding remarks

The doctoral dissertation presented by Mostafa Abotaleb, MSc, Eng., is a high-quality work in terms of both the theoretical development and practical engineering achievements in the analysis of wired and wireless shipboard measurement and control systems, especially in terms of their cooperation. The author has demonstrated good insight and proficiency in the field of maritime shipboard measurement/control. The work is in the field of discipline: Automation, Electronics, Electrical Engineering, and Space Technologies (Polish: "Automatyka, Elektronika, Elektrotechnika i Technologie Kosmiczne).

Because of the above, I hereby recommend that Mostafa Abotaleb, MSc, Eng, be admitted to the public defense of his doctoral dissertation in this discipline.