Preprints of the 19th World Congress
The International Federation of Automatic Control
Cape Town, South Africa. August 24-29, 2014

Industrial Wireless Instrumentation and the Current Commissioning Model

Carlos E. S. da Costa, Ivan Muller, Jean M. Winter,
João C. Netto*, Carlos E. Pereira
Electrical Engineering Dept., *Informatics Institute
Federal University of Rio Grande do Sul
Porto Alegre, Brazil
carlos_c@brturbo.com.br,
{ivan.muller, jean.winter}@ufrgs.br,
cpereira@ece.ufrgs.br, netto@inf.ufrgs.br

Ricardo R. Ramos
Petróleo Brasileiro SA - Petrobras
Rio de Janeiro, Brazil
ricramos@petrobras.com.br

***Abstract*— The commissioning process in industrial automation systems is currently undergoing a transformation to overcome previously gaps between the assembly and delivery of equipment for operation. Wireless instrumentation is increasingly gaining ground on the development of communication protocols and by this, it deserves proper commissioning techniques. The robustness of these protocols is closely related to commissioning, which must provide procedures and techniques to enable proper operation so that the process instrumentation is secure and reliable. An improperly designed commissioning for wireless industrial networks may lead to poorly linked devices due to improper positioning or under coexistence issues. The method proposed in this paper is intended to suggest a specific procedure for the commissioning of wireless instrumentation networks using the modern practice of commissioning.**

Keywords*— comissioning; wireless industrial networks; WirelessHART protocol.

I. INTRODUCTION

The commissioning of wireless industrial networks is an important subject that has been slowly taking shape in the market in which the robustness is a must. Among the technology options for industrial instrumentation and control there are three major standards for wireless networks. They are the ISA SP 100.11a, *Wireless*HART (WH), and WIA-PA. The WH is the evolution of HART for wireless networks and boasts architecture for field devices, access points, and gateways based on HART standard. ISA SP 100.11a employs a backbone router architecture based on IPv6 addresses with 16, 64 and 128 bits. The usage of these technologies is interesting due to the suppression of cabling, which leads to the following advantages: (i) reduced installation time for field devices, (ii) savings in design, assembly and infrastructure, (iii) flexibility to configure devices and updates to existing architectures, (iv) the easy placement of the instruments in hard to reach places inside the plant [1].

In order to make a comparison between the technical commissioning of wired and wireless instrumentation, it is necessary to evaluate the act of commissioning a machine today. This action can be defined as a structured set of knowledge, practices, procedures and skills applicable to complex engineering products in order to ensure its operability and ensure their reliability. Currently, commissioning represents practices that enable the start of the plant operation or the end of a work with efficiency, security and also economic gain. Thus commissioning techniques go on to become a milestone in the search for the best performance and quality in equipment and systems, providing correct installation procedures to supply industrial plant.

In this paper, an industrial wireless commissioning practice is addressed, presenting their challenges and the directions for adequate practices. Section II presents a background about commissioning procedures and Section III, a brief overview of WH protocol. The proposed method for wireless network commissioning is presented in section IV. The case study and conclusions are presented in Section V and VI.

II. BACKGROUND

Under current commissioning procedures, there are some necessary definitions for better understanding of the subject. According to current local standards and rules, commissioning is the structured set of knowledge, practices, procedures and applicable skills in an integrated way to an installation, in order to make it operational within the desired performance requirements. The main objective is to transfer the installation procedure for the operator quickly, orderly and safely to ensure their operability in terms of performance, reliability and traceability information. Thus, the commissioning procedures are composed of several sub-processes, which are specified in next section [2, 3].

A. Preservation

According to the standards, preservation is the set of activities performed on commissionable items in order to keep them in good storage conditions from the time of receipt until the time of their preparation for use. Warranty is assured if the proper maintenance is performed.

The initial stage of preservation activities is the Receiving Inspection. At this stage, one must perform the inspection in quantitative and qualitative way in accordance with the equipment and components received. Any component or equipment can be classified as a commissionable item, such as a tool, equipment, accessory, piping, control loop area, or automation function, as they may change the process.

B. Conditioning

Conditioning is the set of activities performed on all commissionable items and loop installation in order to get them to the stage of Operation and Pre-Departure, aimed at mechanical completion certification. The Blank Test runs at the conditioning stage. After assembly and interconnection of electrical equipment, all loop power, grounding, control, communications, and interlocking should be tested by injecting signal or other form of tests that ensures its continuity. It should be executed after completion of the respective system loop to be tested.

The test certification is also performed in the conditioning phase. It is composed by any tests, measurements, and calibrations performed on a commissionable item or loop without applying electric, pneumatic or hydraulic (injection of signals to performing electrical tests do not characterize energy application). Certification tests are applicable to electrical, mechanical, instrumentation and piping items. The instruments already come factory calibrated, but usually, when they reach the site of installation, they must be checked for a possible recalibration due to the way it was stored or transported [4]. The components that are subject to certification tests must be identified by tags, date, and responsible person for the execution of services. The mechanical completion inspections represent the release of systems and subsystems for the pre-operation, enabling energization of equipments and start of functional activity tests such as functional tests of groups of items.

C. Pre-Operation and Start

In this phase, performed functional tests are done, which basically consist in verifying the installations and performance of equipment when fed by their energy sources. The systems and subsystems are not actually under load during these tests. Instead, they are intended for verifying the operation of items when energized (it is not intended to evaluate equipment performance). Anomalies are recorded at the end. For the execution of functional tests, it is required that the inspection of mechanical completion has been performed previously and the equipment and installation must be in a condition to be released. Tests loop are also performed at this stage and are applicable to electrical control circuits, measurement, communication, instrumentation and control and are designed to verify the performance of devices and components, from a remote control signal (automatic or manual).

D. Assisted Operation

Assisted Operation begins from the transfer to the operator of the first operational system, and ends after expiry of a pre-established period after the transfer of the last operational system. The qualifications and conditions of service level should be defined by contractual arrangements, to ensure the continuity of the system. The Completion of Assisted Operation marks the completion of the commissioning scope. Thus, start phase is defined as performing the final tests until proof of compliance with design specifications.

III. WIRELESSHART NETWORK FUNDAMENTALS

The WH is a communication protocol for wireless mesh networks in the universal 2.4 GHz band with centralized management. It was fully developed for industrial applications being the first reliable and secure protocol for harsh environments [5]. Its physical layer is based on IEEE 802.15.4-2006 protocol and the data link layer is TDMA based. The 10 ms time slots are grouped in periodical superframe structures for data, alarm, and broadcast propagation. Network layer is responsible for messages routing that is done by means of static graphs or source routing, previously generated and downloaded by the network manager. Transport layer is responsible for grouping of messages while application layer is legacy HART command request/response based. WH presents the advantage of integrating with traditional HART networks via wireless adapters.

The WH technology has four main elements: field devices, gateway, access points and a network/security manager. The field devices are the WH sensors, actuators, adapters or routers. The gateway enables the communication between the plant host applications and the wireless mesh network itself. The access point provides the interface between the gateway and the mesh network, formed by field instruments. The network manager is responsible for creation, configuration and maintenance of the network through the programming of communications between field instruments, messages routing and monitoring the overall condition of the network. The network manager can be integrated into the gateway and the wireless access point, forming a single device usually called WH "gateway". An overview of a WH network architecture can be obtained from Figure 1. It is possible to identify the key elements that form these networks.

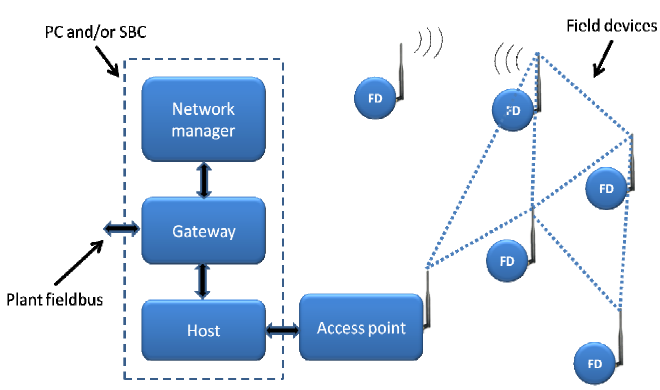

Fig 1. *Wireless*HART network overview.

IV. METHOD

The proposed method aims to detail the commissioning stages of an industrial wireless network, focusing on the analysis of the design, installation, and certification of communications in industrial environment, in order to have a greater system reliability, reduced rework and optimization of execution time. It is recommended to carry out a site survey at the plant before the commissioning, targeting the mapping of the frequency spectrum, which may indicate the presence of interferences.

A. Commissioning starting point

According to [6], in order to start an efficient commissioning procedure, one must critically analyze the design and documentation as a whole. This serves to identify deviations earlier in order to obtain great reliability, avoiding rework during the installation and commissioning of field devices.

The project scope is one of the first documents to be analyzed. It defines the project goals and checks if critical or noncritical instruments (for example, the variable monitoring process and control systems) are present. As part of wireless networks scope it is imperative to analyze radio link aspects, such as network coverage area, the placement of equipment in the field and the possibility of coexistence with other wireless networks. The area density and primary and secondary instrumentation are subsequently considered. The automation architecture should be detailed, clearly showing network types and protocols involved.

When planning the network there are several ways to allocate devices. Related to wireless instrumentation, a new feature in the commissioning procedures is the placement of access points and repeaters, if they are necessary. Simulation software can be used to predict device's placement [8]. As WH forms mesh networks, instruments are connected each other but not necessary directly with the access point, although it is recommended at least 25% of the network forming direct link to access point in order to reduce latency. Data sheets and instrument inputs and outputs should reflect new wireless related information, such as join encryption key, network identifier, refresh rates or burst rates, service type (sink, source, intermittent), threshold levels and RF output power.

Concerning loop diagram, it should show each full loop, from the field instrument location to control or supervising system. The functions, indicators and alarms should also be considered. The drawing scale is intended to define signal coverage, type of antenna to be used (directional or omni directional) and RF output powers. The memory map must have a table containing all the information that will be provided by and to the network. The importance of these maps appear at the moment to integrate the field devices to the control systems. The wiring diagrams show the power details which are supplied by batteries (typically sensors) or conventional line power (typically actuators). Considering other details, any unobserved errors may generate faults in the final assembly, which will result in additional time to detect and correct at the end of installation.

To obtain a secure commissioning, no effort should be made during the design and planning of an industrial wireless network. These efforts are aimed at minimizing the likelihood of failures during startup.

B. Devices configuration

The devices configuration on the network must meet the following steps:

- Gateway power supply and configuration;
- Installation of power supplies (typically batteries) for the field devices, one by one. At each power up, network identifier, join key, and RF power must be supplied;
- Settings of service, burst rate, thresholds, according to process control demands;
- Check if the field device joined the network using a handheld or another tool, then check the normal operation through the gateway, especially the real time demands achievement and packet loss counters.

For the rest of commissioning, network devices must be configured in sequence. Examples of configurable devices are the gateway (responsible for communication with plant host), inspection tools, adapters and human machine interface (HMI).

Considering the parameters to be configured on these devices, the following are the most important:

- Addressing;
- Engineering unity;
- Redundancy parameters;
- TAG;
- Control logic;
- Thresholds and alarm set-points;
- Communication parameters (refresh rate);
- Battery voltage check;
- Necessity to include repeaters for area coverage.

Adequate design documents such as memory maps, logic diagrams, data sheets, technical specifications, engineering flowcharts, points and adjustments lists, avoid configuration errors, especially between devices that have to be integrated, where any error in the parameters avoid the fundamental communication. In the specific case of the WH, commissioning is carried out through the maintenance port that is a mandatory item on all WH certified equipment [7].

There are errors that do not cause frequent communication failures and thus, do not involves interpretation and visualization in the supervisory system (or HMI). Still, they are important and deserves attention. For example, the RF connections levels between the instruments, missed packages, errors in the tagging, engineering units and other non essential for normal operation. These errors affect tests, since they demand time to correct for proper operation.

With all the devices installed and configured correctly, commissioning can be fast, going to its final stage without delays.

C. Security aspects

The access to the WH network is allowed through the management of security keys (join, session and network keys), which provide the connections between the instruments. These may be fixed or rotating, managed by the WH security manager. Depending on the network management policy, the network key can be fixed or refreshed periodically. Join key is directly managed by the manager and permits new devices to be aggregated into the network. The advertisement process, which permits new devices to join network, can be stopped to avoid unwanted network growth.

D. Tests to be performed

Blank tests are performed before energizing the system, when measurements are made on the network, evaluating whether the measured values are in line with those expected by the standard and required procedure. Currently, there is still no standard procedure for WH commissioning, being used HART and some common practices for traditional RF systems . Each network has a report with specific benchmarks to clarify the presentation of results.

Upon completion of blank test, functional tests are performed and the system must be energized to verify the communication parameters. Making an analysis of the network is essential to the final outcome of the tests. It should be taking measurements based on the comparison with standard values, indicating which parameters are in agreement with expectations. Each of the parameters is displayed with the current values, minimum, and maximum obtained in a given time interval.

Network analyzers are used to perform various analyses in communication, checking if any abnormality is present. Analyzers are found for each type of network [9]. In general, the wireless network analyzers do not cause interference when inspecting the network. Data can be available by direct usage of a network analyzer connected to a computer with the information, that is online displayed or it can be stored in the analyzer's memory and subsequently collected. An important analyzer feature is the ability to generate reports that contains the network assessments, using as reference the characteristics of regulatory standards for the network in question. This allows reliable analysis of the results and didactic reports.

The loop test is used to test all instruments, equipment and devices belonging to the same network, simulating a real monitor, command, and control. This is the last step in commissioning industrial networks, and therefore, should be performed carefully, using check lists with responsible signatures and folders filed with the instruments commissioning.

V. CASE STUDY

Currently in Brazil, wireless instrumentation networks are being used in oil and gas industry, primarily for tests and evaluation purposes. Every technology application in this industry requires high reliability regarding instruments, control equipment and systems, besides the capability to be operated in hazardous environments. Given the context, the proposed method is analyzed in two case studies.

The first case study demonstrates the installation of a wireless network to monitor and control the height of the oil column in three storage tanks (15 m height, 40 m diameter). The three tanks are separated by 120 m distance. Three wireless monitoring devices are used: level, temperature, and on-off valves with transmitters (one for each tank). The exit pipe collects the product of three tanks. A motor pump assembly is employed in order to raise the pressure and flow of transported product by sending to an intermediate pumping station. The pumps have bearings with wireless vibration sensors. The pumps are 15 m apart from the first tank. The system diagram is shown in Figure 2.

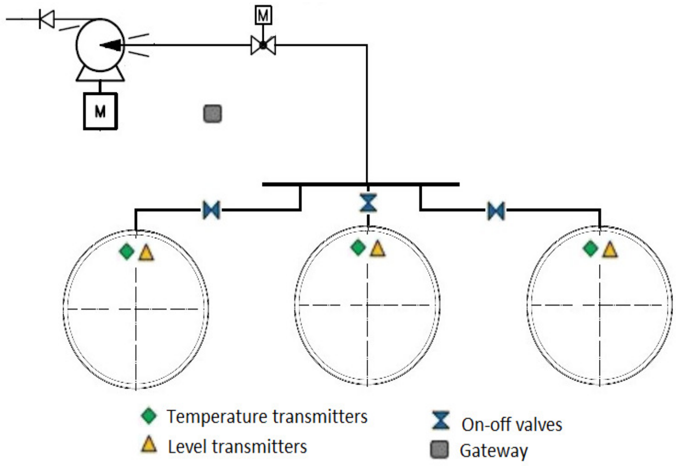

Fig 2. System diagram for case study 1.

One gateway was chosen and placed to form a line of sight with the three tank sensors, creating a star like network topology. Redundant links among field devices were created by the network management. It was found that the refresh rate should be greater than one minute to all devices, which afforded a contribution to increasing the sensor's battery life. The blank test and loop tests were performed and resulted correctly, allowing the official delivery for the normal operation.

A second case study proposes the installation of a wireless instrumentation network in a refinery operating unit. The two distillation units consists in many civil and steel structures with medium and large buildings. One of the field device placement can be seen in Figure 3.

Fig 3. Picture of an installed field device for the second case study 2.

The dimensions of the plant units are 50 x 100 meters each. Fourteen temperature sensors were installed with their respective transmitters. A second unity was also instrumented after the first tests. Each of these units are independent networks with their own gateway, forming a single mesh network. WH gateways (Figure 4) were strategically placed to cover most of the area, being the uncovered part, attended by the mesh network by means of communication multi hops.

Fig 4. A *Wireless*HART sensor and gateway placement.

The instruments are spaced each other from 5 to 20 m. The gateway is placed 20 to 70 m far from the field devices.

The commissioning phase occurred as expected, leaving only the device specific aspects used to analyze communication, which in turn impacted in the final phase of the commissioning process (testing and certification of the mesh network). More specifically, the tools do not allow knowledge of the communication paths, those that instruments and the gateway use to transport information through the mesh network. The gateway web interface for network configuration and usage shows several data in which the messages traverse the network, but does not tell which one is the main path and does not report information on the quality of the signal. Another important point to note is that 3 of the 50 batteries for the transmitters presented problems during the initial period of installation. In this case, the aspects that concern the reliability are harmed due to the high initial failure rate, with malfunction characteristics related to raw materials and manufacturing processes that do not meet specification standards. One could relate the poor battery life due to high refresh rates of the network, but this is not the case because in this application, the employed rate was 1 minute, which does not produces high energy consumption.

VI. CONCLUSION

This paper presented definitions and methods for a best practice in commissioning applied for deployment of today wireless instrumentation, especially *Wireless*HART networks. The critical analysis of the project documents was considered, even ways to keep the instrumentation in perfect condition through the preservation during the commissioning phase and their respective tests. These are part of the needs to make wireless networks capable of being integrated to any process.

Related to case studies, the wireless instrumentation network worked as expected in general, but the IHM should give more information for users. To become more reliable, it will require further improvement as needed for monitoring processes and also, closed loop systems.

The reliability aspect presented some issues, related to redundancy (alternate paths), in the face of possible connection losses and immediate referral to another route. In this case, there is a lack of information from the systems, or they are too slow to satisfy user's needs for clarification. Also, the battery reliability turned into a concern due to lack of tracking information and reasonable failure.

This study intended to produce a procedure for commissioning industrial wireless networks, serving as a benchmark to identify gaps that can make these networks fragile, presenting low performance and reliability. The Blank test, the loop tests, and associated documentation generated in commissioning folders, served to formalize and give support to the client or operator.

For a future study, it is suggested the development of a commissioning software that can be fed with information from the wireless devices on line, enabling the evaluation of the network and its tendency to a possible vulnerability.

ACKNOWLEDGMENT

We would like to express our gratitude to CNPq and Capes, our governmental commissions for post graduation and research on their support for this work. Also, we thank Petrobras for all the funding and technical support to the first R&D projects of *Wireless*HART technology since 2007 within our research group at UFRGS.

REFERENCES

[1] Caro, D. Wireless Networks for Industrial Automation. North Carolina: Ed. ISA Press, 2004.

[2] Bendiksen, T.; Young, G. Commissioning of Offshore Oil and Gas Projects. USA, Author House, 2005.

[3] HARTER, K. Power System Commissioning and Maintenance Practice. USA, Institute of Electrical Engineers, 1998.

[4] Horsley, D. Process Plant Commissioning – UK, Institution of Chemical Engineers, 1998.

[5] Chen, D.; Nixon, M.; Mok, A. WirelessHART Real-Time Mesh Network for Industrial Automation. New York: Ed. Springer, 2010.

[6] Mota J. F. S., Oliveira, R. P.; Pinto N. T. M. Comissionamento em Sistemas e Dispositivos Interligados Via Redes Industriais. Intech Núm. 40, 2012 p. 37-44. Available in www.isadistrito4.org.

[7] Lima, C. P., Muller, I., Winter, J., Netto, J., Pereira, C. E. Porta de Manutenção para Comissionamento e Análise Local de Redes WirelessHART. Congresso Brasileiro de Automática: CBA, 2012. v.1, p.4923–4929.

[8] Kostadinovi, M.; Bundalo, Z.; Bundalo, D. Planning and management of WirelessHart network. International Convention, MIPRO, 33., 2010, Opatija.

[9] Han, S., Zhu, X., Mok, A. K., Chen, D., Nixon, M.; Pratt, W., Gondhalekar, V. Wi-HTest: compliance test suite for diagnosing devices in real-time wirelesshart network. IEEE Real-Time and Embedded Technology And Applications Symposium, 15., 2009.