Wireless Sensor Networks for Industrial Process and Industry 4.0

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***Abstract* — Industry 4.0 has gained attention and space within the strategies of production processes. Its implementation uses concepts of cyber physical systems, internet of things - IOT and cloud computing. Cyber-physical systems allow the monitoring of industrial processes by iterating with the virtual world by establishing decentralized decisions. The internet of things enables cyber-physical systems to communicate, cooperate, and interact with humans in real-time through cloud computing enabling monitoring and decision-making through active participants in the system value chain. Wireless sensor networks have gained more space with the evolution of transistor, sensor, MEMS and microprocessor technologies. The networks are formed by sensor nodes that have reduced physical characteristics and can be applied in several areas, such as monitoring of risk areas, environmental parks, historical monuments, military, domestic, hospital and industrial. The wireless sensor network technologies are supported by simulators that allow the analysis of the best deposition, communication, energy consumption and performance, as well as physical structures that allow to establish better practices of production and maintenance. This paper analyzes the relationship between industry 4.0 and wireless sensor networks for the monitoring of industrial processes.**

Keywords — Industry 4.0, Sensor Networks, Monitoring Condition, Industrial Processes.

I. INTRODUCTION

Industry 4.0 or the fourth industrial revolution is an expression that encompasses technologies for data exchange facilitating the vision and execution of intelligent factories or processes. Has gained space between industrial technological development since it aims at reducing production costs and adds value to the productive chair, establishing decision-making in a decentralized manner. The main features of the 4.0 industry project are to establish processes for interoperability, virtualization, decentralization, real-time capability, service orientation and modularity. The networks of wireless sensors within the aspects of integration of the cyber-physical environment, allow the establishment of solutions that can allow the monitoring of the processes and their consequent taking of actions. Wireless sensor networks are being used in a wide range of areas, such as military, tourism, education, inventory control, monitoring of hazardous areas, environmental parks, historic ruins, military, domestic, hospital and industrial environments. A wireless sensor network is used in situations where it is not possible to use cables and wires. In industrial processes wireless sensor networks can be used with several objectives when associated with reliability techniques, predictive maintenance, and support for preventive and corrective maintenance processes. Wireless sensor networks can be applied to reliability processes, which aim to achieve a certain operational campaign in a certain period without failures. Monitoring of critical conditions indicated in the processes may allow increased reliability. When applied to the RCM technique, Reliability Centered Maintenance, hidden fault detection can employ sensors and eliminate the root cause of failure. Wireless sensor networks in relation to their physical characteristics are formed by many devices, which have the capacity for sensing, processing, actuation, and communication. The main characteristics of a sensory network are sensor, observer, and phenomenon. The sensor is the device that makes the wireless sensor networks are being used in the most military, tourism, education, inventory control, risk areas monitoring, environmental parks, historical ruins, military, domestic, hospital and industrial environments. A wireless sensor network is used in situations where it is not possible to use cables and wires. In industrial processes, wireless sensor networks can be used with several objectives when associated with reliability techniques, predictive maintenance, and support for preventive and corrective maintenance processes. Wireless sensor networks can be applied to reliability processes, which aim to achieve a certain operational campaign in a certain period without failures. Monitoring of critical conditions indicated in the processes may allow increased reliability. When applied to the RCM technique, Reliability Centered Maintenance, hidden fault detection can be used to detect sensors and eliminate the root cause of failure. Wireless sensor networks in relation to their

physical characteristics are formed by many devices, which have the capacity for sensing, processing, actuation, and communication. The main characteristics of a sensory network are sensor, observer, and phenomenon. The sensor is the device that makes the monitors the magnitude or phenomenon being analyzed. The element of sensor, processor, radio, and battery form its basic

TABLE I. MAINTENANCE AND APPLICATION TECHNIQUES

Techniques	*Application*
Preventive: technique based on time or condition	Monitoring parameters of filters, collectors, cameras, supporting decision-making for anticipation or postponement of campaigns.
Predictive: technique based on resulting analysis	Vibration, temperature, and noise monitoring. Allows support for investigation of hidden failures.

structure. The information collected are sent to the observer. The observer is the user who wishes to obtain data about the phenomenon monitored. The phenomenon is the greatness or object of study of the observer. Among the limiting and critical factors for wireless sensor networks is the question of substitution due to consumption. Wireless sensor networks are being used in a wide range of areas, such as military, tourism, education, inventory control, monitoring of hazardous areas, environmental parks, historical ruins, military, domestic, hospital and industrial environments. A wireless sensor network is used in situations where it is not possible to use cables and wires. In industrial processes wireless sensor networks can be used with several objectives when associated with reliability techniques, predictive maintenance, and support for preventive and corrective maintenance processes. Wireless sensor networks can be applied to reliability processes, which aim to achieve a certain operational campaign in a certain period without failures. Monitoring of critical conditions indicated in the processes may allow increased reliability. When applied to the RCM technique, Reliability Centered Maintenance, hidden fault detection can employ sensors and eliminate the root cause of failure. Wireless sensor networks in relation to their physical characteristics are formed by many devices, which have the capacity for sensing, processing, actuation, and communication. The main characteristics of a sensory network are sensor, observer, and phenomenon. The sensor is the device that monitors the magnitude or phenomenon being analyzed. The element of sensor, processor, radio, and battery form its basic structure. The information collected are sent to the observer. The observer is the user who wishes to obtain data about the phenomenon monitored. The phenomenon is the greatness or object of study of the observer. Among the limiting and critical factors for wireless sensor networks is the question of substitution due to consumption. Thus, the establishment of efficient protocols can allow the prolongation of the useful life of the system. The main metrics for evaluating the protocols are energy efficiency, latency, precision, fault tolerance, scalability, and sensor exposure. Important requirements for receiving and transmitting data securely are defined as data confidentiality, data authentication, data integrity, and data being recent.

II. RELATED TECHNOLOGIES

The industry 4.0 uses for the integration of the diverse processes technological concepts for the integration of the systems. These processes are defined as additive manufacturing, artificial intelligence, internet of things, synthetic biology, and cyber-physical systems.

TABLE II. RELATED TECHNOLOGIES

Technologies	*Characteristics*
Additive Manufacturing	Additive Manufacturing or 3D Printing is the addition of material to make objects, made up of several parts, constituting an assembly.
IA - Artificial Intelligence	Segment of computing that seeks to simulate the human capacity to reason, make decisions, solve problems, providing software and robots with an ability to automate multiple processes.
IoT - Internet of Things	Allows establishing the connection between physical objects and the Internet, executing in a coordinated way certain action.
Synthetic Biology	Uses the convergence of technological developments in the areas of chemistry, biology, computer science and engineering, enabling the construction of new biological parts such as enzymes, cells, genetic circuits, and the redesign of existing biological systems.
Cyber Physical Systems	Systems that synthesize the physical and digital worlds, establishing a digital copy in the physical world cloud.

The related technologies still have other characteristics that establish the foundation of interactivity of workings. Among these characteristics we have:

Interoperability: The ability of systems, humans, and plants to connect to each other and through the internet and cloud computing.

Virtualization: deals with the creation of plant plants and processes through interconnected data sensors and simulation models.

Decentralization: skills that cyber-consumer systems have to make decisions without human intervention.

Real-Time Capability: Ability to collect and analyze data and take knowledge derived from it immediately.

Service Orientation: offering services through cloud computing.

Modularity: The adaptation of the requirements of mutants or expansion of individual modules.

III. Applications of wireless sensor network

The technological advance has allowed the diagnosis of active equipment in relation to its operating condition and availability. The applications of the wireless sensor networks allow the analysis of conditions of temperature, vibration, pressure, among other magnitudes allowing the intervention in the equipment in a suitable time avoiding the breakage or loss of total function. Several works have used wireless sensor networks for process monitoring. The works are aimed at monitoring the processes with the objective of detecting the failure and guaranteeing the reliability of the process.

TABLE III. Detection

Process	***Application***
Environment	Pollution: gas, noise Danger: flood, debris Security: surveillance
Monitoring conditions	Structural health: buildings, wind turbines, coal mines, tunnels, and bridges Equipment conditions: pipes and machinery
Automated processes	Evaluation: water consumption, electric energy, and supply chain; Improvement: field irrigation, precision and viticulture, air conditioning control and production automation.

machines and the use of monitoring equipment is demonstrated. [14]

IV. Commercial solution

Commercial solutions for wireless sensor networks. Wireless sensor networks have commercial solutions that allow the implementation and monitoring of quantities within industrial processes. Acquisition of data through sensors such as vibration, temperature, humidity, among others allow the processing of signals using signal conditioning software, tracing the diagnosis of equipment or process failures. Classifying the monitoring process in condition environmental, monitoring and automation conditions we can deploy process variants according to the need for detection. Commercial solutions for wireless sensor networks. Wireless sensor networks have commercial solutions that allow the implementation and monitoring of quantities within industrial processes. Acquisition of data through sensors such as vibration, temperature, humidity, among others allow the processing of signals using signal conditioning software, tracing the diagnosis of equipment or process failures. Classifying the monitoring process in condition environmental, monitoring and automation conditions we can deploy process variants according to the need for detection.

A. Environmental Detection

For environmental detection the sensors should be studied and implemented to withstand local conditions and deterioration caused by the medium. Sensors must be of adequate protection, prone to mechanical shock, wind, humidity, corrosion caused by the environment or even by animal feces. This robustness is one of the implementation challenges since it causes a significant increase in network cost. Buying this balance of costs with the implementation of the network, also allows the detection and prior preparation of resources, equipment, structures, or populations monitored. The environmental impact of the reliability processes can make business continuity unsustainable. Breaking environmental standards involves much more than productive losses, but fines, significant losses of the biome and socio-economic losses. Monitoring of hazardous, risk or safety conditions are variables that can be monitored by wireless sensor networks.

B. Condition monitoring

The condition monitoring of equipment and systems is one of the essential conditions of the reliability of processes. Reducing the rate of structural, mechanical, electrical, or electronic failures depends on the monitoring and the equipment degradation curve interval. The critical break point in the degradation curve is the element that should be avoided because it establishes the most cost to reestablish the line or process. The technology allows the establishment of sensors embedded or embedded in the equipment to monitor the operating conditions. The hardware and firmware solutions in sensors can establish the detection in real coding. The impact on productivity for industry 4.0 is one of the aspects favored by real-time detection, optimizing processes and especially addressing adverse conditions in equipment and processes.

C. Process automation

Wireless sensor networks can be established in conjunction with industrial process automation. The traditional design of automation seeks to establish homogeneous systems for the detection of production lines. The sensors, deposited previously or in an embedded way, allow to establish heterogeneous constructions and to establish the necessary detection to the process. The mobile applications for logistics, continuous monitoring of energy processes, productive among others are examples of networks that can be established. The goal of an automation is to seek the reduction of human resources safely, reliably, using only the amount of resources required. Wireless sensor networks allow this iteration when associated with traditional formal detection processes in applications.

TABLE IV. COMMERCIAL SOLUTION

Provider	*Environmental*	*Condition*	*Automation*
ABB		Equipment	Evolution Improvement
Accutech Instruments		Equipment	Evolution
AES	Pollution Danger	Structural Equipment	Evolution Improvement
Emerson		Equipment	Evolution Improvement
Endress+Hauser	Pollution Danger	Equipment	Evolution Improvement
Hitashi	Pollution Danger Safety	Structural Equipment	Evolution Improvement
Panasonic	Pollution Danger	Equipment	Evolution Improvement
Pepperl+Fuchs		Equipment	Evolution Improvement
Rockwell	Pollution Danger Safety	Equipment	Evolution Improvement
Siemens	Pollution Danger Safety	Structural Equipment	Evolution Improvement
SKF		Structural Equipment	
Timken		Equipment	Evolution Improvement
Wessex Power	Pollution		Improvement

V. CONCLUSION

Wireless sensor networks enable important contributions to the monitoring of industrial processes. The techniques of preventive and predictive maintenance can be followed by parameters such as temperature, vibration, pressure, among other magnitudes. The technology of the sensor nodes allows through different operating systems the integration of the monitored environment with efficient, lean production techniques and direct the internet applications of Industry 4.0. Several works have presented the advantages of network applications for monitoring environments hostile to conventional monitoring, as well as show substantial savings in deployment resources when compared to conventional networks. Quality parameters such as latency, mobility, implemented medium and transmission capacity are indicated as elements that indicate the quality of networks and are described as wireless industrial networks. Applications are described in industrial processes with the objective of monitoring environmental conditions, risk, and safety. The application of wireless sensor networks to monitor industrial processes can allow substantial gains to the reliability and physical integrity of existing processes.

ACKNOWLEDGMENT

We thank the Polytechnic School of USP for the opportunity.

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