Wireless Sensors in Industrial Instrumentation

A Survey

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***Abstract* - While the technological evolution of sensors is reflected in sensors getting smarter, smaller, lighter, and cheaper, another key development taking place in the sensors industry is the growth of wireless sensor use in industrial applications. Industrialists and Manufacturers recognize that wireless sensors can offer cost reductions, but more importantly, they see wireless sensors/technologies as an enabler of entirely new business processes that not only will be less expensive, but safer, more reliable, and far more transparent than their current manufacturing, production and instrumentation processes. This paper intends to give an overview of wireless sensors that are applicable in Industrial Instrumentation and Control.**

***Keywords:* - Wireless Sensors, Industrial Automation Sensors, Survey of Smart Sensors in Industrial Application,**

I. INTRODUCTION

During the last decade, the use of sensors and sensor networks has been in rapid development and grown considerably in a variety of applications, specifically in industrial field, enabling the remote control and automation to improve the safety for plants and production facilities in food, chemistry, automotive, railway domains[1]. Many researchers and engineers have discovered that wireless sensors play an important role in processing of the data and should not be viewed as simply a substitute for traditional tethered monitoring systems[2]. Wireless sensors are the standard measurement tools equipped with transmitters to convert signals from process control instruments into a radio transmission. These radio signals are converted into specific, desired outputs such as an analog current or digital signal with the help of receiver. Perhaps wireless sensors are best viewed as a platform in which mobile computing and wireless communication elements converge with the sensing transducer and the greatest attribute of the wireless sensor is its collocation of computational resources with the sensor.

With the wireless sensors offering impressive computational resources for processing the data, software embedded in the wireless sensor with network only represents one half of the complete wireless sensing unit design; hardware wireless sensor represents the second half. With computational power coupled with the sensor, wireless sensors are capable of autonomous operation[2]. Being able to sense strain, heating, and other factors in industrial instrumentation is useful and desirable. The traditional method for such instrumentation requires running wire to each and every sensor, a difficult, expensive, and failure-prone process, particularly when literally millions of sensors may require instrumentation. It has been estimated that typical wiring cost in industrial installations is US$ 130–650 per meter and adopting wireless technology would eliminate 20–80% less than of this cost[3]. Without a physical link existing between individual wireless sensors and the remainder of the wireless sensor network, wireless sensors must know when to act autonomously or collaboratively.

Wireless sensors can be used for the applications that are difficult to access due to the high temperature, high pressure, and hazardous chemical environments etc. Due the wireless sensors applications, operators can continuously monitor and supervise the processes in hazardous environments from control room located at safe and distance away from factory floor. Integrating the wireless sensors with industrial processes and control systems have significant advantages and require guaranties for real-timeliness, functional safety, security, energy efficiency, etc. [4, 5].

In this review paper, we are exploring the wireless sensor applications for the industrial instrumentations and control processes. The organization of this paper is as follows. Section 2 covers hardware requirements of the wireless sensors. Section 3 is the discussion on potential industrial application and related works. In section 4, advantages and future of the wireless sensors are explained. Finally, section 5 concludes the survey.

II. HARDWARE CONSIDERATIONS

Practical wireless sensors are small wireless sensors, which mimic the mounting of traditional wired transducers. For instance, pressure sensors incorporated by a male pipe thread connection, accelerometers with a stud mount and temperature sensors which are configured in a standard thermo-well configuration. Each of these designs imposes volume constraints. Additionally, the volume and mass of the device shouldn't require additional structure to support it. This inherently limits energy storage.

The architectural and circuit design technique for a wireless sensor operating at low power places demands on all levels of the design. An architecture for achieving the required low energy operation and the circuit techniques necessary to implement the system incorporates dedicated hardware implementations to improve the efficiency for specific functionality [25].

Power is of concern in every design decision. Practical options for powering are stored energy or environmentally harvested energy. These are frequently described as battery vs. power harvester. Sensors are designed to be powered continuously. Stored and harvested power sources pose distinctly different design challenges [26].

There are two major obstacles. The first is to generate enough power from the environmental energy source. This involves an intermediate energy storage device, usually a capacitor or rechargeable battery. The second obstacle is the intermittent nature of the source: sunlight isn't available at night. This requires larger intermediate energy storage or acceptance that the system just won't work all of the time.

A harvester wired to the sensor eliminates the need for intermediate energy storage. If the sensor already has energy storage, the responsibility of the harvester is reduced. A balance between the two would be the optimal configuration once harvesters achieve a level where they can reliably and practically provide a consistent low power level from environmental energy at a cost, volume, and complexity that is consistent with market demands [26].

III. INDUSTRIAL APPLICATIONS

Advances in miniaturization and integration of electronic and mechanical components will enable sensor with a size of a few cubic millimeters in the near future. At the same time, an ongoing price decline will allow the replacement of conventional wired sensors in many areas [20].

1. Wireless smart sensor platforms targeted for instrumentation and predictive maintenance systems have been developed. The platform has plug-and-play capability, supports hardware interface, payload and communications needs of multiple inertial and position sensors, and actuators, using a RF link (Wi-Fi, Bluetooth, or RFID) for communications [21].
2. Environment control systems - Wireless sensors can be used to ensure the indoor environment of living spaces is in an acceptable condition for living. Indoor air quality monitoring systems involve actual gas sensing, sensor networking, data mining and decision making. Accurate measurement of gas concentrations is the key of air quality monitoring. And this can be kept within the budget of the monitoring system as well [22].
3. Safety systems – Building evacuation procedures can be implemented using wireless sensors. Generic techniques rely heavily on strategies planned in advance of the actual event. The procedure is static, unable to adapt to changing environmental variables, and no real world data is available. These methods are effective for only permanent inhabitants and completely disregards evacuation procedure awareness for once-off visitors. Wireless sensor procedures address these issues allowing the rapid and intelligent evacuation of a building [23].
4. Space Technology - Wireless devices do not require wiring trunks to connect sensors to a central hub. This allows for easy sensor installation in hard to reach locations, easy expansion of the number of sensors or sensing modalities, and reduction in both system cost and weight. This provides a number of possible benefits in spacecraft design.

Sensing infrastructure is no longer fixed after spacecraft design and manufacture, re-locating a sensor from one panel to another is easily accomplished if needed. Finally, wireless sensors are re-used between vehicles once their initial missions end. Re-purposing wired systems is much more difficult, as it needs wiring to be stripped from one craft and re-strung in another and necessitating substantial disassembly of spacecraft in both cases [18].

5. Monitoring and Supervisory Control - The evolution of sensor technology and communication networks has allowed employing intelligent sensors for improving the processing control. In this case, sensors not only collect data but also perform some local processing and later transmitting their results through a wireless channel; thus, there is no need for a wired communication infrastructure [24]. In addition, by allowing the sensor nodes to perform some local data processing, data channel utilization can be improved by not transmitting redundant data. For example, one can choose to send an RMS value instead of all the individual acquired values for the posterior processing in a remote unit [25].

IV. ADVANTAGES & FUTURE

Intelligent wireless sensor have drawn industry attention due to their reduced costs, better power management, ease in maintenance, and effortless deployment in remote and hard-to-reach areas. They have been successfully deployed in many industrial applications such as Maintenance, monitoring, control, security, etc.[6, 7]. Currently the possibilities and needs of the wireless sensors in all the industry sectors and branches are wide spread. The pace of industrial development pushes and encourages the development of Wireless sensors and networks even more. In this chapter, we analyze and evaluate current Wireless Sensors and discuss possible future trends in this area. In the industrial field, processes modernization and industrial automation through the introduction of advanced technology, intelligent sensors have greater progress and made the productivity improve and production costs decline[8].

In today's modern and competitive industry marketplace, it is the need of each company to improve the product and the process efficiencies with compiling all environmental regulation and financial objectives[9]. Traditionally, industrial processes and the control systems communicated and monitors all the inputs and outputs through wired network. However wired communication and sensors are costly, required regular maintenance, difficult to troubleshoot, high failure rate of connectors and have to run all wires and cable over the factory floors. As the wires ages, they can crack or fail and inspecting, troubleshooting, testing, repairing, replacing requires time, cost, labor, material which leads to production stoppage. In 1997, [10, 11] the President's advisers on science and technology asserted that the development of wireless sensors could improve production efficiency by 10 percent and reduce emissions by more than 25 percent. To overcome the disadvantages of wired sensors, industry must invoke new measures to improve production performance and safety while minimizing costs and extending the operational life of new and aging equipment[12]. The collaborative nature of the wireless sensor offers the following advantages,

1. Lower cost – the maintenance and installation cost continue to drop day by day due to wireless sensors. According to [13], Venture Development Corporation survey found that the lower cost of wireless sensors attracting most of the industry for adaptation.
2. Most of the failures in processes or systems causes due to wire connectors, which can be reduces by wireless sensors.
3. The wireless sensors offer more flexibility to plant managers, engineers, operators as they are free from wire. The process parameters and materials can be monitored, track and more easily reconfigure, control the assembly lines, industrial processes as per the need of customers demand.
4. Integrating wireless sensors with industrial processes and systems is more reliable than the wired sensors, as wireless sensors can offer built-in redundancy and capabilities for anticipatory system maintenance and failure recovery.

5. Faster data transmission and commissioning can be achieved by using the wireless sensors.

The transmission of data from wireless sensors to the Programmable Logic Controller (PLC) or Supervisory Control and Data Acquisition (SCADA) for process control and monitoring uses wireless networks such as wireless mesh network, ZigBee network, Bluetooth, wireless LAN etc[14]. The wireless sensor technology has proven and demonstrated as a great ability, potential for industrial process control, data monitoring of processes parameters such as temperature, pressure, flow, humidity, level, density, viscosity, vibration intensity, quality etc[15]. The wireless sensor nodes operates on battery power, hence the data dissemination protocols, many routing systems have been used are specially design with power management and energy awareness [16].

The future for wireless sensors is poised to have a promising growth. As the technology is realized that will enable a wireless transducer to perform as an equal to a wired unit, that growth will increase [17]. While this technology offers unprecedented flexibility and adaptability, implementing it in practice is not without its difficulties [18];

1. Energy constraints are widely regarded as a fundamental limitation of wireless and mobile devices. For sensors, a limited lifetime due to battery constraint poses a performance bottleneck and barrier for large scale deployment [19].
2. With respect to achieving reliability that is on par with wired sensor approaches, any practical wireless sensor deployment must contend with a number of difficulties in its radio frequency (RF) environment including multi-path reflections and interference from other systems [18].
3. Bandwidth availability for communications limits the information bandwidth of the device, it limits the number of independent sensors that can operate simultaneously, and sample rate of sensors.

V. CONCLUSION

The survey paper aims to give perspective on the introduction, evolution and future of wireless sensors in the field of Industrial instrumentation. The flexibility of wireless sensors makes them very useful for applications that must have the installation freedom of wireless devices. This means that every wireless sensing unit must have a balance between the competing requirements for low power consumption, long transmission ranges, and the ability to calculate complicated structural engineering algorithms on-board.

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