Smart Lighting For Ex Industrial Applications: The Illuminating System Of The Future

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Abstract -
Any industrial facility or manufacturing process must operate safely, effectively, and productively, so lighting devices are essential. They are the only source of illumination for activities that are confined to darkness and work continuously. On the other hand, facilities such as oil & gas, refineries and petrochemical plants must face and overcome the inherent difficulties of hazardous, as well as provide light. The energy savings from intelligent management of lighting systems, combined with the high degree of control that these solutions offer to the end-user and the possibility to schedule maintenance, make smart lighting technology the best candidate for the Ex lighting systems of the future. Therefore, smart lighting deserves proper attention and exploration, which is why this research was chosen.
The Paper begins with a brief overview of lighting systems, followed by the theoretical foundations related to smart lighting systems. The research also includes a market analysis of major companies involved in smart lighting solutions, highlighting the need for reliable and safe lighting solutions that comply with industry standards.
This paper contributes to the existing body of knowledge by providing a practical solution for smart lighting in various environments and particularly for Ex ambient.

Index Terms — Ex, ATEX, IECEx, Oil&Gas, DALI, Smart Lighting, Lighting control system

I. INTRODUCTION

A lighting control system, sometimes called “Smart lighting”, is simply the application of a control system to a single light source or a network of light sources. This control system (automated or not) allows the user to control the lights switching on and off, the light intensity (dimming) and light color emitted, create complex light patterns or designs, and so on.

Furthermore, many smart devices are capable of interfacing with each other via an Internet connection (or other protocols discussed in the next paragraphs), thus ensuring that they can communicate data on their operating status and receive instructions on their behavior. By this capability, these smart devices allow for intelligent light management, because they can illuminate only where needed and when needed.

The latest smart lighting systems are often controllable via phone apps, allowing for a comfortable and convenient user experience that can manage his lighting apparatus with a touch of a finger. The ratio of energy savings from intelligent management of lighting systems to the consumption of the intelligent management system is remarkable, making this technology the best candidate for illuminating the smart cities of the future.

The main tasks that smart lighting offers to solve are:

- remote management of lighting fixtures, including monitoring their operation or any problems;
- monitoring of energy consumption;
- automation of operation, with intensity adjustment and more significant energy savings;
- collection of data from the territory, including environmental data (e.g., related to air quality) and dissemination of information to the citizen of daily utility or even in case of emergency situations;
- traffic monitoring.

Smart lighting systems could also be very useful in the Ex world. Nowadays, they are not widespread in this kind of industries, but many manufacturers are beginning to implement smart solutions in hazardous areas, as will become clear later. The reasons are: the high degree of control these solutions offer to the end user, the huge energy savings, the reduction in maintenance time, and the possibility to schedule maintenance in hostile environments, such as offshore platforms. It is much safer and more convenient to know exactly when, for example, a fixture has failed and needs to be replaced, rather than sending an operator out every day to check if the device is working properly by a visual inspection.

Nowadays, there are available technologies to manage lighting systems in Ex environments. However, these solutions must be tailored to the specific needs of the customer, making things more difficult and expensive. Therefore, one of the challenges will be to implement these technologies on a larger scale. Furthermore, because of the energy carried by Electromagnetic (EM) waves, there are issues associated with implementing wireless controls in these environments.

II. EXPLOSION ATMOSPHERE

One of the most challenging industrial environments is the Ex-environment, such as an Oil & Gas field, where an explosive atmosphere could be often present [1].

An explosive atmosphere is a mixture of flammable substances in a gaseous, foggy, vaporous state, or powder mixed (will later be called more simply GAS and DUST) with air, under certain atmospheric conditions in which, after ignition, the combustion propagates itself to the flammable mixture. A potentially explosive atmosphere is obtainable only if the concentration of the flammable substance is not too low (lean mixture) or too high (rich mixture): in these cases, a combustion reaction may occur, or even no reaction at all, but no explosion [2].

As the explosion triangle in Figure 1 shows, an explosion can occur only when all three elements are present simultaneously: fuel, combustive agent (oxygen) and ignition source.

Therefore, to avoid a gas explosion, it is mandatory to exclude one or more of them, and to make electrical equipment safe, three different principles can be applied, which act differently on these three elements of the triangle. These three different principles are:

- *containment method*, the parts that can cause ignition are included in a box made to withstand the pressure of the explosion, preventing the spread of *flame*;
- *prevention method*, in this method the necessary measures are taken to avoid excessive temperatures and the creation of sparks, thus eliminating the *ignition* source;
- *segregation method*, in which active components are separated from the explosive mixture using resins, sand, oil, preventing any contact with oxygen and fuel.

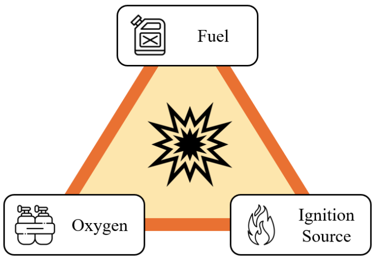

Figure 1 – The explosion triangle

All the protection modes for Ex environment are derived from these three different principles, and these protection solutions can also be used for Luminaires [3].

The *containment method* is related to Ex-d (Flameproof enclosure) mode of protection, in which parts that can ignite a potentially explosive atmosphere are surrounded by an enclosure that resists the pressure of an explosive mixture exploding inside the enclosure itself and prevents the transmission of the explosion to the external atmosphere surrounding the enclosure [4]. It is very important to design the length, the gap and roughness of the joint between cover and enclosure body according to the Standard.

The *prevention method* is related to the Ex-e or Ex-i protection mode. Ex-e (Increased Safety) mode involves the application of additional measures to the electrical equipment to increase the safety level, thus preventing excessive temperature development and the formation of sparks or electric arcs within the enclosure or on exposed parts of the electrical apparatus, where such ignition sources should not occur under normal service conditions [5]. Ex-i (Intrinsic Safety) is where current, voltage and power values are considered intrinsically safe. This means that under any operating condition or lack of maintenance, it is not possible for sparks or overheating to occur which ignite an explosive atmosphere.

The *segregation method* is related to the following modes of protection: Ex-m, Ex-p, Ex-o and Ex-q. Ex-m (Encapsulation) protection consists of covering the components which might produce sparks or over temperatures with a resin which is resistant to environmental conditions. Ex-p (Pressurized) exploits the segregation technique by preventing access to explosive atmospheres by the insufflation of an inert gas or air into the enclosure, in this way the internal pressure is maintained higher than the external one. Ex-o (Oil Immersion) exploits the principle of segregation by using Oil as a filler. Maintenance is obviously difficult as the container must be emptied of oil and, after any maintenance and/or repair work, refilled. Furthermore, systems are required to guarantee a constant level of oil. Ex-q (Powder Filling) protection involves filling the enclosure with a material, normally quartz powder, which under normal conditions prevents the transmission of sparks to dangerous atmospheres outside.

III. SMART LIGHTING SYSTEM STRUCTURE

A smart lighting system suitable for deployment in hazardous or explosive atmospheres, relies on a few basic components, as shown in Figure 2.

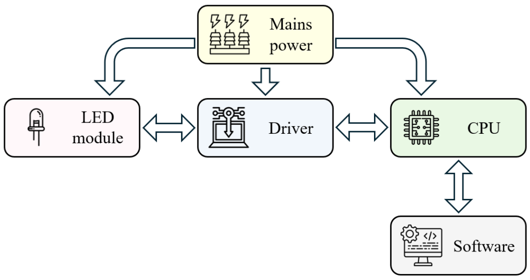

Figure 2 – Basic lighting system structure

Hardware, in the context of computer or electronic equipment, comprises tangible and manipulable components. These components form the backbone of any system, and their proper functioning is of paramount importance for system efficiency and safety. Concerning smart lighting systems for hazardous atmospheres, hardware elements include the mains power supply, LED modules, drivers, CPU (or controllers) and their respective printed circuit boards (PCBs). Each individual component must be evaluated from the perspective of igniting an explosive atmosphere. Each component that is part of the hardware system must therefore be protected with one of the possible types of protection (IEC EN 60079-xx). The most common protection methods for luminaires include Ex-m (encapsulation) or Ex-d (flameproof enclosure), but these are not the only ones.

The central device responsible for generating light in these systems is the *LED module*. These modules consist of PCBs that house arrays of LEDs. These PCBs are strategically mounted on heat sinks to guarantee an efficient LEDs heat dissipation. LED modules are available in various sizes and configurations, which allow to decide each parameter such as colour temperature, colour rendering index (CRI), luminous flux, and beam angle to achieve precise lighting effects in line with the requirements of the lighting function and of hazardous settings.

Compared with traditional lighting sources, such as incandescent or fluorescent bulbs, LED modules offer many advantages. They have higher energy efficiency, longer lifespan, lower heat emission, and compatibility with various dimming and colour control methods. This is why incandescent and fluorescent lamps have been banned in Europe. This versatility allows unparalleled flexibility in lighting design, which often requires LED modules to be arranged in arrays or clusters within the lighting system to meet specific lighting performances and requirements. All new LED luminaires for hazardous environments use an Ex-m (IEC 60079-18) protection mode for the optical part, which provides greater efficiency, reduced weight, and lower production costs than other possible protection methods.

Another essential component is the *driver*, which consists of a PCB enclosed in a protective casing and integrated with various components. PCBs assume a key role in modern lighting systems, facilitating the electrical connections between components and thus ensuring system reliability and efficiency. The LED driver's primary function is to regulate the current and voltage supplied to the LEDs, thus ensuring their secure and effective operation. Furthermore, LED drivers often offer advanced control functions, including dimming, colour control, and programmability, thus improving the adaptability and flexibility of lighting design. LED drivers are industrial drivers not used for applications in explosive environments. Therefore, a solution must be found to prevent this component from becoming an ignition source. The simplest solution usually adopted is to install these drivers in small Ex-d enclosures (IEC 60079-1).

The centre of the system is the *Central Processing Unit (CPU)* or microcontroller, often referred to as the "brain" of the system. The CPU is responsible for processing incoming data and executing the imperative instructions that are essential to the smooth operation of the system. In smart lighting systems, the CPU interprets input signals from a myriad of sources, including sensors, switches, and remote controls. It processes this data to precisely adjust lighting output parameters, including brightness, colour temperature, and specific lighting effects. Moreover, the CPU can react to environmental factors, thus facilitating intelligent adjustments of light output and improving energy efficiency and user experience. The CPU also plays a key role in supervising the lighting system's operation. In case of malfunctions or failures, it provides diagnostic data. This functionality increases system reliability, reduces maintenance expenses, and minimizes downtime, all of which are of primary importance in hazardous environments. As just mentioned, the CPU is an important electronic equipment for the proper operation of the entire system. It is also an industrial component produced by major lighting electronics manufacturers. Again, it is easy to find this equipment installed in Ex-d enclosures or in environments not classified as hazardous areas.

The *mains power* supply, which is the main electrical power source of lighting systems, provides standard alternating current (AC) electricity from the grid. This AC power source supplies the LED driver, which is responsible for converting AC to direct current (DC), which is essential for the operation of LED modules. Generally, the mains power supply is connected to the LED driver via wiring harnesses or connectors. In this context, the LED driver employs a big number of electronic components, including diodes, capacitors, and transformers, to perform the conversion of the AC voltage from the mains into the DC voltage essential for the LED module operation. In environments that prioritize safety and reliability, such as hazardous settings, the mains supply takes on a critical role in ensuring the operation of the entire lighting system.

In the end, another important part of the basic lighting system structure is the *software*. It is important because it is the user-device communication system. The software allows each individual device to be controlled and information to be received from it.

IV. CONTROL OPTIONS FOR SMART LIGHTING

Control options have evolved considerably with the advent of electronics, facilitating more accessible and economical lighting management. Historically, manual dimmers and switches prevailed, making remote control impractical. This section examines the evolution of control techniques and protocols, focusing on the most common and widespread methods, their functionality, and associated advantages and drawbacks.

The objective is to provide an overview of available control options, clarifying the rationale behind protocol selection for the final prototype.

A. - Cabled Solutions – Analog Standards

In the 1980s, the quest for energy efficiency spurred the development of analog controls for commercial lighting. Initially designed to control fluorescent ballasts and dimmers from a single source, analog control techniques have since evolved to meet different needs [6]. Basically, analog dimming modulates the drive current supplied to a lighting device. Maximum current is used to achieve maximum brightness, and brightness is adjusted by changing the current within the device circuit. Although analog dimming minimizes output noise, it can cause colour variations as the current decreases. However, analog dimming has limitations at low dim levels, where light uniformity and colour stability can be compromised.

A.1 - 0-10V "Standard"

The 0-10V "standard" is a prevalent analog control protocol, prized for its simplicity and historical popularity in the entertainment industry. Although not internationally regulated, it is defined by standards such as IES Standard 60929 Annex E and ESTA E1.3 [7], which specify control types: current sinking and current sourcing.

In current sinking, a controller generates a DC voltage and adjusts the luminaire’s brightness by varying the voltage delivered. In contrast, current sourcing involves the luminaire itself producing the control voltage and the controller using a variable resistor to ground the voltage, adjusting the brightness.

The 0-10V protocol offers intuitive operation, ease of installation, and cost-effectiveness. The voltage range aligns with dimming levels (0V for off, 10V for maximum brightness), expressed as a percentage of output. Although, it is widely used in commercial setups, there are compatibility challenges due to the absence of international regulation.

A.2 - 1-10V Standard

The 1-10V standard is an improved version of its predecessor, recognized by the international standard IEC 60929 for the control of lighting ballasts. It operates in a voltage range 1-10V to safeguard against electrical noise and extend driver life.

This standard imposes control curve criteria and requires that driver operate as current sources and controllers as current sinks. The 1-10V standard includes provisions for insulation, polarity-free wiring, and device voltage tolerance.

1-10V control minimizes dependence on the power grid, increases independence from dimming, and incorporates an "off" function. However, it cannot control different lighting groups and operates as a one-way communication protocol.

A.3 - PWM Modulation

PWM modulation is recognized as a valid control method by the IEC 60929 standard for electronic drivers. It works on the principle of rapidly opening and closing a circuit switch at a given voltage or current level. Since LEDs emit light when a current flows through them, the total LED illumination time varies according to the switch's operation.

The key parameter governing the PWM dimming process is the duty cycle, represented by the ratio of the "on time" to the sum of the "on time" and "off time", as reported in the following equation.

$$\delta = \frac{T_{ON}}{T_{ON} + T_{OFF}}$$

This duty cycle, indicated as δ, controls the final brightness of the device. Since PWM operates at a high speed, imperceptible to the human eye, the intensity of emitted light varies according to the duty cycle chosen.

PWM modulation requires a switching frequency of at least 1kHz to avoid flicker. However, a high frequency can introduce noise and interference, especially as the cable length increases. Moreover, lower frequencies can cause discomfort or visual disturbances to people with sensitive eyes.

In contemporary lighting applications, PWM is less used for dimming due to its higher cost, potential flicker below 100 Hz, strobe effects in fast-moving environments, and electromagnetic interference caused by the rapid rise and fall of lighting due to the same variation of current during PWM dimming. However, it can be integrated into control devices compatible with standard digital protocols such as DMX or DALI, topics that will be discussed in detail in following Sections.

B. - Cabled Solutions - Digital Standards

For many years, the lighting control industry was dominated by proprietary protocols, but as demand for lighting equipment and electronic devices increased, concerns about compatibility between different devices led to the adoption of digital standards. These standards ensure that manufacturers adhere to specific protocols, eliminating interoperability issues between products, even if they are made by different companies.

The United States Institute for Theatre Technology (USITT) was one of the first to introduce digital standards. In 1980, it developed the AMX192 multiplex analog protocol for controlling dimmers, intended primarily for the entertainment industry. However, nowadays the analog nature of this protocol has made it obsolete.

B.1 - DMX512

DMX512, which stands for Digital Multiplex Data Transmission Standard for Dimmers and Controllers, is a widely adopted digital standard for communication networks. Originally developed to standardize the control of dimmers for stage lighting, DMX512 has found applications in various fields, from Christmas lights to large concerts in stadium.

DMX512 allows up to 512 dimmers to be controlled, and each channel represents a control channel. The system works by sending numerical values to control brightness, with 0 representing off and 255 indicating maximum intensity. Each controlled light fixture is assigned an address, usually a number between 0 and 255, to adjust the brightness. The controllers transmit packages to lights in series, and the package with the corresponding address adjusts the brightness of the respective light fixture.

DMX512 works with a unidirectional protocol, in which data is sent from the controller to the devices but is not returned by them. As described, DMX512 Universes can control up to 512 channels, and large control desks or operator consoles used during events can handle multiple universes.

Despite its popularity, DMX512 has some limitations, including resolution constraints, limited capacity, lack of error correction, and signal distribution difficulties due to cable length limitations. In addition, the installation process can be less intuitive, and visible "jumps" between brightness levels can occur when dimming at low settings.

The effectiveness and reliability of DMX512 in entertainment lighting control is well-established. However, it is not suitable for applications with stringent safety requirements, such as pyrotechnics or ATEX, which involve life safety considerations.

B.2 - DALI

The Digital Addressable Lighting Interface (DALI) protocol was designed specifically to meet the needs of commercial and architectural lighting, distinguishing itself from previous protocols that were aimed primarily at the entertainment industry. Developed in 1999 by Philips, Osram, and Helvar for the control of fluorescent lamp, DALI has found applications in a variety of industry sectors [6].

DALI works on the principle that each device in the system has a load interface, that allows it to communicate with other DALI devices on the same network and with control devices through a pair of wires. This bidirectional protocol allows information to be exchanged in both directions, from sensors to controllers and vice versa.

A typical DALI network includes a bus power supply, an application controller, control devices (such as ballasts or drivers), and input devices (such as sensors and buttons) with DALI interfaces. Each device has a unique short address between 0 and 63, which allows up to 64 control gear devices and 64 control devices to be configured on a single basic network. The bus handles both signalling and power distribution, typically providing up to 250 mA at 16V DC, with devices drawing up to 2 mA each for DALI control.

Unlike DMX512, DALI is a proprietary brand of the Digital Illumination Interface Alliance (DiiA). DiiA is a global consortium of lighting companies focused on growing the market for lighting control solutions that use the standardized DALI protocol. DALI-compliant products obtain the DALI trademark only after they passing DiiA testing, ensuring interoperability between devices from different manufacturers. DALI is ideal for lighting control of large rooms or suites of rooms, but is not suitable for building-level control solutions [8]. If necessary, it can be easily integrated with higher-level control systems, such as gateways.

Key features of DALI include ease of installation with reduced number of wiring, support for individual and group control, address configuration without physical switches, the ability to query devices with back data, low susceptibility to electrical noise, and a standardized dimming curve designed to match the light sensitivity of the human eye.

B.3 - DALI2

DALI2 represents an improved version of DALI developed by DiiA. To achieve DALI2 certification, devices undergo rigorous testing and certification by DiiA. New features of DALI2 include improved multi-vendor interoperability, more detailed product testing procedures, and the inclusion of control devices such as input devices and application controllers.

The DALI2 protocol also includes a subsection known as D4i. D4i certification is granted to DALI LED devices that meet DALI data, power supply, and D4i specifications for control devices. These specifications include luminaire data (DALI Part 251), energy data (DALI Part 252), diagnostics data (DALI Part 253), integrated bus power supply (DALI Part 250), and more [9]. D4i-certified devices enable real-time performance monitoring, diagnostics, energy measurement and other advanced functions, making them especially valuable for various applications, including highly explosive environments. While DALI devices may be optional, these functions are mandatory for D4i devices.

C. - Wireless Solutions

Wireless control is gaining popularity, especially in industrial applications, due to its convenience and the absence of cumbersome cable configurations. Wireless lighting protocols operate primarily in the radio frequency spectrum, ranging from 100 MHz to 6 GHz. A wireless lighting network comprises several essential elements:

- a driver or ballast that converts control signals into the actual lighting output;
- a control device to send commands to the driver;
- a wireless communication device often connected to the control device to enable communication;
- a server that handles complex interactions within the lighting network;
- a gateway that acts as a bridge between lighting devices and a central server;
- software that facilitates communication between the user and the network;
- additionally, the network topology plays a key role.

The main two common topologies are *Star Topology* and *Mesh Topology*. In *Star Topology* a central hub connects to the internet and manages all operations, relaying commands to peripheral devices. However, the network nodes do not communicate directly with each other. In *Mesh Topology* (a mesh network) peripheral nodes can communicate with each other. The nodes in a mesh network possess the processing power and memory necessary to support routing functions, which improves network robustness.

Wireless options can be categorized into three main groups, as summarized in Table 1:

- *Low Power Short Range*: commonly used for home applications, characterized by a mesh topology, and operating between 700 MHz and 2.4 GHz. The best-known protocols are Zigbee, BLE Mesh, Casambi, and Thread;
- *Low Power Long Range (LPWAN)*: used in IoT applications and smart city lighting networks, it operates in a star topology between 180 kHz and 2.4 GHz. LPWAN offers long-range operation, low power consumption, and cost-effectiveness.
- *High Power Wireless*: operating on frequencies up to 5 GHz and with star topology networks, this category is ideal for applications that require transmission of large amounts of data. Examples include Wi-Fi, 4G, and 5G.

The choice of wireless solution depends on factors such as application data requirements, coverage area, robustness, and cost.

It might seem counterintuitive that low-power long-range communications can cover greater distances than high-power wireless. This distinction derives from the specific applications for which each type of wireless is designed. Low-power long-range communication, or LPWAN, excels in scenarios that do not require high data rates, while high-power wireless is designed for applications that involve significant data transfer, such as video and audio.

Table 1: three categories for Wireless

Category	Distance	Frequency range
Low-power short-range	Up to 300m	700 MHz – 2.4 GHz
Low-power long-range	Up to 50km	180 kHz – 2.4 GHz
High-power wireless	Up to 100m	Up to 5 GHz

V. SMART LIGHTING IN EX ENVIRONMENTS

As will be discussed in the next paragraph, smart lighting is not widely used in the Ex-world. Technology in this area always comes a little later than in the “traditional” industrial environment, because technical standards for the prevention of explosion risks are not so rapid in their evolution. In any case, the benefits of using this new technology are very significant.

To make the environment safe, the refinery or on-shore/off-shore platform is usually located in remote places.

Particularly for unmanned platforms, it becomes essential to be able to remotely manage all luminaires, turning on or off, activating or deactivating special signaling devices according to the specific situation on the platform (presence of gas, helicopter landing), and reducing the light intensity of luminaires in areas where this is possible.

These aspects, not only have the advantage of energy savings, but especially that of not having to send personnel for some tasks that can be performed remotely in a better efficient way. As a result, maintenance costs can be strongly reduced.

On the other hand, when considering large refineries or large oil and gas plants, where thousands of luminaires are installed, maintenance and detection of faulty ones can become much easier and faster. In this case, we are not talking about scheduled maintenance, but extraordinary maintenance due to luminaire failure.

In fact, the smart lighting application makes it possible checking and evaluating the proper operation of each luminaire in terms of temperature and electrical parameters. The actual placement in the system is known, so when a problem is seen at the PC workstation, the luminaire can be easily and quickly replaced.

Another important aspect to consider in a hazardous atmosphere is the type of connection (wired or wireless). In both cases, the requirements of the installation standard for these environments (IEC 60079-14) must be met. Also, for the wireless version only, it is important to consider that transmission from the wireless can be an ignition source for explosive atmospheres (see clause 6.7 of IEC 60079-14:2013). Standards IEC 60079-0:2018 in Clause 6.6 specifies what the data transmission limits are depending on the type of GAS or DUST present in the explosive atmosphere.

VI. STATE OF THE ART AND MARKET ANALYSIS

The analysis focuses primarily on the ATEX/IECEx industry, as it addresses specialized and hazardous environments. This industry tends to progress at a relatively slower pace than the general lighting industry, which includes lighting fixtures for non-Ex environments, home applications, and IoT.
Data relevant to this analysis were collected through online research. The analysis was organized into a table (ANNEX A, in the end of the Paper) listing companies and their details. The table includes categories such as "Company name", "Field of application", "Luminaire type" and "Protocols".

Furthermore, the analysis covers the following Ex application areas:

- *Cabled*: custom-designed wired solutions for Ex (explosion-proof) applications, including explosion-proof luminaires;
- *Wireless*: wireless solutions specifically developed for Ex (explosion-proof) applications, including explosion-proof luminaires;
- *Wireless/Cab*: solutions that can be implemented in both cabled and wireless configurations for Ex (explosion-proof) applications, including explosion-proof luminaires.

It is worth noting that the market is predominantly oriented toward industrial products, which are versatile to meet different needs. These industrial products make up the majority of available solutions. In contrast, products designed for Ex (explosion-proof) applications are typically customized to meet the specific requirements of individual customers, given the unique needs of industries operating in hazardous environments. This specialization and customization are key factors contributing to the slower technological progress of the Ex-sector compared to the industrial sector.

The analysis clearly shows that the protocol preferred by companies is DALI. Almost all the listed products support the DALI protocol, indeed 87% of the products analysed use it; 90% of manufacturers with a Smart device in their portfolio have at least one product with a DALI protocol. This prevalence is due to the many advantages offered by DALI, including ease of installation, device interoperability, cost-effective implementation, extensive possibilities for customizing the final product (such as scenes, devices, colours, etc...), and the ability to control numerous devices with only two wires. Moreover, the limited use of cables allows luminaires to be arranged in an organized manner, facilitating future maintenance work.

Another noteworthy aspect concerns D4i and DALI2. As discussed at the beginning of this Section, the Ex-world tends to progress more slowly than the general industrial world due to market and standards dynamics. Currently, none of the Ex-manufacturers have adopted D4i-certified solutions. However, it seems inevitable that more and more companies will start implementing such products, especially in Ex environments. Functions such as DALI Part 251 - Luminaire Data, DALI Part 252 - Energy Data, and DALI Part 253 - Diagnostics Data, will be essential for managing lighting systems in hazardous locations. These functions increase the safety of the operator and maintenance personnel and allow for scheduled or on-demand maintenance, optimizing the use of resource.

Additionally, 0/1-10V controlled lighting luminaires still account for a significant part of the market. On the other hand, DMX is more commonly used in the entertainment industry.

As for wireless devices, the options are very wide for industrial and home applications. However, as mentioned above, when it comes to Ex environments, regulations impose limits on wireless device installations. Appropriate protective devices must be used, and they must adhere to the allowed power limits. This often raises costs, making a wired solution more appropriate. However, specific situations may justify the installation of a wireless lighting network in hazardous areas, although these cases must be analysed on an individual basis.

In conclusion, another very important aspect is that all Ex-luminaire manufacturers offer the “smart lighting” solution only on request and not as a standard product. They offer the option of using a “smart driver” instead of the non-dimmable industry standard. There are several reasons for this, most notably the higher cost and the more limited operating temperature range of the smart driver. Furthermore, the fact that a true “smart” package is not provided still makes the solution unattractive.

VII. CONCLUSION

Smart lighting is simply the application of a control system to a single source or a network of light sources. As discussed in this Paper, there are many control possibilities, and each has advantages and disadvantages.

Although the technological progress in the Ex-sector is moving ever more slowly, the most of manufacturers of luminaires for hazardous environments provide a “smart lighting” solution only upon request and not as a standard product, only few of them are trying to include this solution in their catalogue introducing a true “smart” package, making this solution more attractive.

When the solution is proposed, one very important aspect is that all Ex-luminaire manufacturers offer the option of using a “smart driver” instead of the non-dimmable industry standard. There are many reasons for this, most notably the higher cost and more limited operating temperature range of the smart driver.

Although this technology is relatively developed in the industrial sector, many globally significant companies continue to invest millions in research and development, demonstrating the validity of these systems.

It will be interesting to see how smart lighting technologies will evolve in the Ex-sector as well, where lighting control systems are critical for the reasons discussed above.

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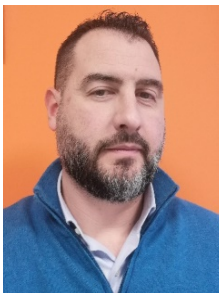
IX. VITA



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COMPANY NAME	Type		PROTOCOLS								
	FIELD OF APPLICATION	LUMINAIRE TYPE	BLUETOOTH	ETHERNET	0-10V	1-10V	PWM	DMX	DALI	DALI2	D4I
Stahl	Wireless/Cabled	Linear luminaire									
	Cabled	Helideck systems									
	Wireless/Cabled	Flood lights									
	Wireless/Cabled	Emergency luminaire									
Zalux	Wireless/Cabled	Linear luminaire									
Warom	Wireless/Cabled	LED down light									
Dialight	Cabled	Obstruction LED lighting									
	Wireless/Cabled	Flood lights									
	Wireless/Cabled	Linear luminaire									
Technor Italsmea	Cabled	Linear luminaire									
Vyrtych	Cabled	Flood lights									
	Cabled	Emergency luminaire									
	Cabled	Linear luminaire									
Tormin	Wireless/Cabled	LED down light									
	Wireless/Cabled	High bay									
	Wireless/Cabled	Emergency luminaire									
	Wireless/Cabled	Flood lights									
Thorne & Derrick int.	Cabled	High bay									
	Cabled	Flood lights									
Eaton	Cabled	Linear luminaire									
Bartec	Cabled	Flood lights									
Cortem group	Cabled	High bay									
	Cabled	Flood lights									
	Cabled	Linear luminaire									

X. ANNEX A