ANSALDO ENERGIA PROGETTO LHP (OR6.3)

Proper management of PPE (Personal Protective Equipment) financed by the Italian Ministry of Economic Development

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Abstract. Ansaldo Energia is a Major Player in Italy for metal mechanic production which decided to adopt Industry 4.0 standards. One of the main projects, at this purpose, was to develop a new vision concerning Safety. The goal was achieved by a Team built specifically by the Company. Particular importance was assigned by the Team to PPE (Personal Protective Equipment), devices designed to improve safety of the Operators in carrying out their duties. The problem that the Team has clearly warned, given the frequency of occurrence, concerns the periodic maintenance of PPE, to be carried out by law for each device, according to precise rules in order to preserve their efficiency as well as safety certification. Therefore, the Team studied a new methodology, the subject of this paper, based on hardware and software tools designed to monitor the legal revisions and critical deadlines of each PPE in use.

Keywords: PPE maintenance, PPE IOT, PPE risk, PPE 4.0.

1 Introduction

As part of the LHP (Light House Plant) project co-financed by MISE (Italian Ministry for Economic Development) for the transformation of Ansaldo Energia into an Industry 4.0 factory, great importance was given to section 6, regarding the safety of operators. The DIME (University of Genoa Department, literally “Dipartimento di Ingegneria Meccanica, Energetica, Gestionale e dei Trasporti”), was in charged as technical and scientific advisor of the project. From a first screening of the literature of the sector, the

authors realized the gravity of the safety problem at a global level. As evidence of this consideration, the data provided by the ILO-International Labor Organization, report that worldwide every 15 seconds an operator dies and 153 are injured, with an annual projection of 1.2 million deaths and 320 million accidents recorded with a consequent overall economic loss of the order of 225 billion USD. The enormity of these data from the economic side, but even more so from the human side, pushed the team to make efforts to make a positive contribution. The LHP project thus became the starting point for conceptualizing and implementing effective solutions. The subject of this paper is the correct maintenance of PPEs (Personal Protective Equipment), which are vital if properly revised and maintained at the deadlines (indicated by the manufacturer and made mandatory by law). Ansaldo and UNIGE (DIME), in this regard, decided to select a technological partner, with specific skills and to build up a multidisciplinary project team to tackle the problem and to conceptualize a new 4.0 system.

2 Literature review (state of the art)

A careful literature review was conducted by researching predominantly on Scopus, WOS and Google Scholar. Over 32.800 papers were found by researching about PPE, filtering initially by “PPE maintenance” and “smart PPE”. The majority of the papers came from Scholar, nevertheless, the most were out of scope. In fact, soon, the authors realized that “smart PPE” was a misleading keyword, as referring to special applications, being not relevant to the current study. Therefore, a first selection was made by restricting to “PPE maintenance”, reducing the paper considered to 17.391. It was then realized that the keyword “PPE maintenance” was used for a wide range of applications, for this reason the topic was focused on Industry, obtaining a further restriction to 299 papers only. The relevance of the articles obtained was higher, but still too much generic. Another filter was then applied, to concentrate the research on the goals of the study, by introducing new keywords like “risk assessment, PPE 4.0, health monitoring, IOT, wearable devices, electronic devices”, shortening the list to 86 paper, which were deeply analyzed, further decreasing the selection to 23 papers, considered totally in line with the goals of this work. This result made the authors aware that literature does not currently treat much about the industrial automatic monitoring of PPE, to improve their maintenance and management. The literature relating to PPE frames the devices under different applications (concerning, for example, the use, the sector, the materials, the way to wear them [1], [4], [5], [7], [8], [9], [10], [11], [12], [13], [15], [17], [19], [23], ..), nevertheless only a part of the same, including that part of literature published by the bodies responsible for the safety of the operators, underlines the great importance of a management of PPE that guarantees: a) efficiency over time, through compliance with the necessary maintenance; b) decommissioning on the expiry dates indicated by the manufacturers.

Inefficient PPEs become, in fact, useless and therefore dangerous for those who feel protected, with consequent risks for the safety of the operators. In this regard, in Italy, INAIL (National Institute for Accident Insurance) in 2019 published the [17], in which it is reiterated that for any device (PPEs included) it is through maintenance that the

preservation of performance and safety features is guaranteed over time. Italian legislative decree 81/2008 in article 78 obliges workers who use PPE to take care of their maintenance. The ISO 14119 standard provides the possible combination between PPE and RFID (Radio Frequency IDentification) and dictates some restrictions on maintenance [22], [3]. In this last article are also included the benefits of the combination of PPE and RFID, a topic which is covered again by the article [18]. The papers [15], [20] emphasize the importance of the maintenance of the PPEs that protect the respiratory tract of the operators. This is because, in the event of a malfunction of the protective equipment, they are led to tamper with it, taking all the consequences for their safety. Commonly used technology for such purposes is the IOT (Internet of Things). The selection reported in the bibliography, mentioned at the beginning of this chapter, cites the extensive literature consulted by the authors on the subject, which highlights what is of specific interest for this paper, in relation to the importance of a correct PPE supervision of dates established for maintenance and legal revisions, and the definitive expiry dates of the same, which concludes their life cycle [2], [3], [6], [13], [16], [19]. The literature review allowed the authors, already convinced by the investigation conducted in the company of the need to create a methodology to monitor the scheduled interventions to keep PPEs in efficiency, to concentrate: a) on devising an appropriate management model of such equipment; b) on conducting an accurate benchmark among the available technologies, to identify the most appropriate one.

3 Case study

3.1 Team Building

After careful examination, Smart Track S.r.l. was selected as most suitable technological partner because of the great competences in 4.0 tracking technologies. Then the extended team was defined:

- Ansaldo Energia S.p.a. (EHS: Eng. Andrea Magro, Coordinator - Eng. Massimiliano Ziveri, Project Leader – ICT: Eng. Stefano Santucci, Head; Eng. Sergio Botti, System Engineer – DATT: Mr. D. Furfaro, PPE Responsible);
- Genoa University - DIME (Prof. Eng. Roberto Revetria, PhD: Scientific Coordinator, Prof. Eng. Marco Mosca, PhD: Technological e Scientific Advisor);
- Smart Track S.r.l. (Technological Partner: Eng. Saverio Pagano, AD, Eng. Simone Peirani, Coordinator, Eng. Alessandro Cortese, PM);
- Futuro S.r.l. (PPE Supplier, Ds. Margherita Pitto, Owner, Mr. Paolo Priano, Interfaccia A.E.).

3.1 Scenario AS-IS (current methodology)

To date, an internal function manages the PPEs manually, by means of registers, on which the manager records personal data, deliveries and withdrawals of new, stored or assigned devices. Despite his efficiency, it is easy to understand the objective

difficulties inherent in this type of activity, based on "many to many" relationships (like manufacturers, PPE, operators, sites of use, …).

3.2 Scenario TO-BE (innovative methodology proposed by the Team)

The activity involves the installation of appropriate sensors on a selection of PPEs associated to an acoustic and visual detection systems, to monitor the scheduled dates both for the periodic revisions and for the expiration dates. The installation of these sensors will prevent any delay in control tasks, thus ensuring PPEs correct maintenance, revision or replacement within the established dates. Also, it will help keeping the operators aware of the importance for safety, of the correct management and maintenance of protection devices. At this point, the team proposed the developed methodology to the manager responsible for PPE. Once agreed on the objectives of this activity, the reference technology was selected, together with the technological partner (Smart Track). All the PPEs in use in the company were carefully assessed and the most suitable ones to start a pilot project were identified. The team therefore launched a specific research project; in the first phase of investigation, some elements of importance emerged, such as the fact that PPEs are subject to legal revisions and do not have an indefinite duration, but a precise life cycle. It also clearly emerged that monitoring and maintaining PPEs requires work, therefore, it is complex and time consuming. Another aspect to take into account is that the assignment of PPEs to operators traveling to construction sites, implies a correct estimate of the duration of the trip and the preventive calculation of revisions / expiration dates. Omission of this practice would expose the company and the operators to risk on safety.

3.3 Benchmarking of technologies

Next step of the project was, for each technology identified, (like bar code, RFID and NFC-Near Field Communication) to highlight the strengths and weaknesses in relation to the specific use. Bar code was a consolidated and low-cost technology. On the other hand, they are not suitable for application on many types of surfaces such as lanyards or any PPE exposed to water; moreover, an uncomfortable reading of the same if placed internally and the ease of deterioration of coded labels. For this reason, RFID were considered, with numerous points in favor including the robustness of the system, the greater amount of information that can be stored on 96bit tags and the possibility of making multiple scanning contemporary. Also, the RFID tags are more compatible than bar codes with the geometry of the selected PPEs. Another point in favor is that these tags, sourced in volumes, are really cheap (in the order of hundredths of Euro). The weakness of this solution, for this specific application, is that the gates to be monitored are many, in fact, the operators can access the workplace from different directions (enter and exit from different doors of the warehouses) and can insist on different work islands both in the factory and at the construction sites. This layout would imply a redundant cost for antennas (the antennas required range from € 600 to € 1000 each). The last technology investigated was NFC, with some favorable characteristics like the practicality of application, since this type of tag can be integrated into the head of an

electrician cable tie. Another strength consists in the ease of reading and the fact that NFC does not require expensive reading hardware, contrary to RFID antennas. In fact, an App for NFC smartphones already enables functions like scanning of the tags and access to the database. Weaknesses of this technology, compared to RFID, are the need to scan every single PPE and the cost of 1,00€ for each tag. At the conclusion of this benchmark analysis, the team selected, for this type of application, the technology offering the best ratio price vs. performance, still guaranteeing effective and efficient performance, represented clearly by NFC.

3.4 Feasibility and sustainability study

Regarding this phase of the project, the team needed to review what emerged from the previous together with ICT (Information & Communication Technology is the internal function managing both the contracts with technical suppliers and the systems installed in the factory). Two other review were held respectively with the DATT (internal function managing and assigning PPEs to operators) and with the external partner supplying PPEs (Futuro S.r.l.), with the scope to present the selection of PPEs identified for the pilot project. In this regard, the team proposed: a) harnesses; b) lanyards; c) electrically ventilated helmets; d) dielectric gloves; e) reels; f) belts. This selection was re-evaluated by the supplier to confirm the suitability. The supplier, as well, contacted each PPE manufacturer to get a written confirmation that the application of the tags cannot be considered as tampering. In this regard, the manufacturers contact, in turn, the relevant certification bodies, to ensure that the application does not cause the decay of the certifications. The outcome of the inquiry made it possible to ascertain that all the selection made was compatible with the integration of the NFC tags, exception made for the dielectric gloves which, if pierced to pass the cable tie housing the TAG, would lose the ability to isolate. The team, then, discharged such glows from the selection and proceeded with a re-evaluation of the remaining, in the field. This phase began with a meeting towards DATT, together with Futuro, to test, from an operational point of view, the application of the tags to each approved PPEs. The authors then proceeded to identify the best application for each PPE, meaning that it should not interfere with the work of the operators, nor generate annoyance, nor be exposed to shocks or sliding. The next steps consisted in: a) design of the operating process; b) design of the smartphone application.

3.5 Framework of the project steps

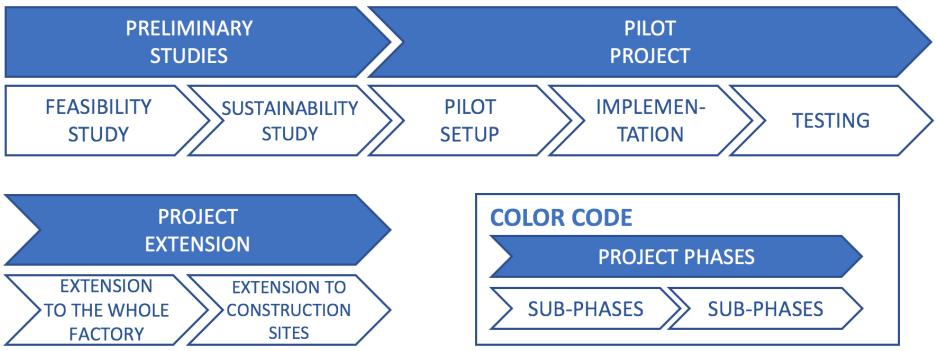

Fig. 1 Process of implementation

The framework proposed in Fig. 1 is applicable on the following conditions: a) full sponsorship of the management, providing a to the project the necessary resources (people and budget); b) creation of an internal function dedicated to the management of PPEs; c) census of PPEs available in the facility (type, supplier, brand, batch number, serial number, expiry date, …); d) selection of the PPEs to be monitored; e) creation of a register for delivery and return of PPEs assigned to operators; f) adoption of the system (server, software, tags, NFC smartphone); g) integration of the tags on the PPEs; h) training to the involved personnel.

3.6 Design of the operational process

The authors then, produced clear photographs for each tag applied, showing the integration with PPEs, to get the approval by the Manufacturer. A new element, fundamental for the correct management of PPEs was to define a reporting procedure to track the equipment along the assignment. Such procedure is divided in 4 steps, appropriately noted in dedicated books: a) written request for PPE by the operator; b) approval by the competent office; c) delivery to the Operator; d) return of the PPE to the office. A similar procedure is used for the replacement of a PPE.

3.7 IIOT (Industrial Internet of Things)

The proposed system acts in compliance with Industry 4.0 standards, adopting the principles of IIOT, like the ability to generate a network of physical objects (not native for Internet connection, properly the selected PPEs), by embedding them with electronics and software, enabling Cloud connection and data exchange. The System, therefore, allows monitoring and controlling functions by a multitude of heterogeneous peripherals such as computers (fixed and mobile), tablets and smartphones. This comes through the designed application or through direct access from the web portal (only for authorized devices, in accordance with cyber security). The impact of the IIOT on industry generates multiple benefits. In this case, starting from safety, but with the

possibility to develop a multitude of applications (like proactive maintenance, predictive maintenance, energy saving, monitoring-control-automation of the infrastructure in real time, integration of heterogeneous devices and of different manufacturers, environmental monitoring, ...). The possibility of centralizing the data, collected at the peripheral level, also allows the development of a high analytical capacity, leading to significant improvement of the process knowledge. Considered the significant number of fatal accidents that occurs every day in industrial plants all over the world, this system represents an asset of a certain importance against both the threats on the safety of the Operators and the economic damage for companies.

3.8 Application for smartphones

The diagram (Fig. 2) represents the architecture of the system, including the smartphone application, created with the aim of exploiting the most of the available technologies offered by a market, which is increasingly based on Industry 4.0.

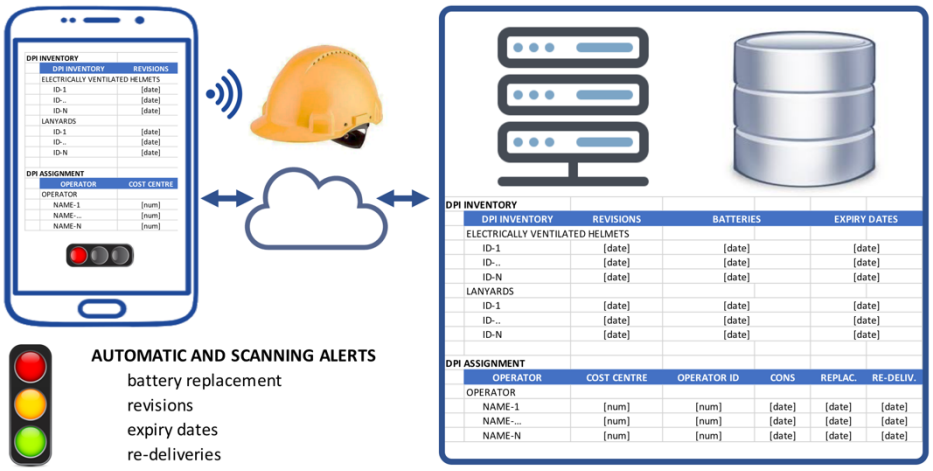

Fig. 2 System architecture

In fact, many of the modern smartphones include NFC technology, which allows the acquisition of information by the appropriate tags, through the direct scanning procedure described above. The application communicates with a cloud hosted on a company server, which records the data on separate channels in a relational database. The analytics software transforms such data into usable information available in tables and graphs. The main table represents the PPEs registry (displaying information relating to the manufacturer, the supplier, the date of purchase, the price, the lead time, the status, the duration of the batteries, the life cycle, the revisions required by law, the dates for replacement of consumables, and the deadlines). A second table records the assignments to operators (registering name, surname, cost center and serial number, in addition to specific usage information such as collection date, possible replacement, delivery, status at the time of collection VS. status upon delivery, any use in emergency that

might have compromised integrity and would require repair / replacement). The application acquires and centralizes peripheral data at the time of each scan and compares such data with the information from the data base. As a next step it returns a simple and direct message to the operator (traffic light logic), where green is used for indicating total usability of the PPE assigned, yellow for partial usability (need for revision / imminent expiry / need to replace consumables / low battery level / ..) and red for non-usability (revisions or deadlines not met / damage not repaired / ..). Clear system notifications, associated to the light code, explain the problems to the operator. The manager has also the option to add information to the data base, or to access the data base in sole reading mode.

3.9 Pilot Project

The pilot project was divided in different phases. Initially, the setup of the project was carried out by selecting the suitable PPEs, the staff to be involved and the responsible for the delivery of PPEs. The full team selected was trained. The information processes and procedures were defined; the specifications of the selected PPE and safety requirements were analyzed. The calendar of the project was planned. Then, the implementation phase started by applying the NFC tags to the PPEs; at this point it was activated a beta application on the server (to be extended, once tested, to the Cloud) and the project was launched. On the implemented system, numerous measurements of operating times and errors were conducted in order to evaluate the efficiency, by comparing with previous measurements. Support to the operators was provided along the whole pilot project. The pilot project allowed to gain experience. A new phase of continuous improvement was started, involving hardware, software, processes and procedures.

4 Results and Benefits

This monitoring procedure brings to the company significant benefits, like: a) a greater safety of the Operators; b) time savings compared to the standard monitoring approach; c) the absence of errors in maintenance, which is required to keep efficiency; d) a longer duration of PPEs (e.g. the damage produced by the spillage of the acid of the batteries, compromising the efficiency of the device); e) the timely replacement, once expired, of the consumable materials (like the headphone pavilions), so preventing operators, annoyed by malfunctioning, to reduce the use (a correct management of consumables also allows for a better hygiene for the operators, as in the case of mask filters); f) the reporting procedures introduced allow great transparency on maintenance procedures; g) the register provided records the assignments, reducing the number of losses; h) the list of PPEs available is constantly updated, providing the manager with a real-time image of the equipment to take the most appropriate measures (as urging operators to return PPEs not more needed; or to provide to the replacement of PPEs or spare parts); i) also a greater competitiveness for the company in the tenders, thanks to the differential that it can boast from competition in terms of the safety in the workplace.

5 Conclusions

PPE from life-saving devices can even generate phases of risk if expired or not properly maintained. This paper tackled the issue of a 4.0 management of PPE to keep them efficient during their life cycle and, upon expiry, to alienate them. The intervention is divided into two phases: a) the development of tracking tools for the delivery / use / return, to be compliant with the specifications; b) the conceptualization and development of a device for on-the-job control by the security staff of the critical revision and expiry dates. This device does not interfere with the wearer's activity and can be used both within the company and on external construction sites. The authors would expect that other companies will quickly follow the example of Ansaldo Energia, which felt the need to adopt an innovative methodology to continuously control PPEs efficiency, to safeguard operators' safety. The design architecture studied by the Team has proven, after a severe test phases, to respond to the needs for which it was conceived, for this reason the authors claim that it represents a real asset for Safety 4.0, where it is made use of PPEs. Particular attention was paid by the team to the standardization and generalization of the new procedure, to develop a system that can be used in every operational situation. Considering the small size of the NFC tag and the ease of integration on most of the PPEs on the market, the proposed system can be standardized for extension to other sectors such as, for example, construction, quarries, plumbing and heating. The IIOT nature of the system allows a further generalization to monitor even other types of devices than PPEs (e.g. special tools, equipment, ...).

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