TEST Engineering & Management

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

Vehicle and People Tracking System Inside an Underground Mine

Dario Utrilla, Nicanor Benites, Alfredo Granados, Rejis Paredes, Enrique Osorio, Wilver Auccahuasi

Universidad Nacional Mayor de San Marcos, Lima, Perú

Article Info
Volume 83
Page Number: 24500 – 24508
Publication Issue:
May - June 2020

Article History
Article Received*: 11 May 2020*
Revised*: 19 May 2020*
Accepted*: 29 May 2020*
Publication*: 12 June 2020*

Abstract

This article presents the design and implementation of a network of RFID (Radio Frequency Identification) antennas, which taking advantage of the laying of the electrical network that is inside the mines, through the same cable is fed to an RF antenna to proceed with the detection or identification of the presence of tags attached to personnel or machinery within the mine. The data in these tags are stored by electronic circuits designed specifically for this purpose. These circuits also respond to a computer that is responsible for exporting said data to the cloud, from where a web page accesses and displays them to anyone without having to be present in the work area. This system will allow them to identify and quantify risks, in addition to increasing the production of mineral extraction and treatment, since, in most concessions, the machinery of small mining is rented for hours, then with the identification of vehicles A financial saving can be generated due to the constant monitoring of the location of said vehicles, and the company will be able to ensure their safety and indirectly control the different processes that are carried out inside it.

Keywords:*Vehicle tracking, Underground Mine.*

I. Introduction

In Peru, mining represents in recent years more than 50% of foreign currency, 20% of tax collection and 10% of GDP, therefore, it has a great impact on the economy. activity, the protection of personnel working in mines and the conservation of the environment is not a simple challenge [9].

Only Large Mining and a certain part of Medium Mining can access expensive technology that allows them to have the entire production process controlled and mitigate the risk of danger to personnel. These actors try to promote the use of modern technology in their operations, protecting and conserving the environment, as well as occupational health and safety. However, we still find operations in medium-sized mining and especially in small-scale mining that try to develop their exploitation projects at the lowest possible cost, putting personnel at risk and not maintaining the minimum standards of environmental conservation, finding in the Most of the cases a lack of order and technology in their mining operations, they work with empirical methods, and they suffer from mining planning, projection and exploration programs, improvement of metallurgical recovery, cost control systems, implementation of security systems, among others [9].

In Peru, between 2011 and 2012, 12,819 minor accidents, 2,886 incapacitating accidents and 101 fatal accidents were registered [7]. The death or disability of a worker due to an accident is a serious personal, family and business loss [1].

Therefore, those underground mining projects in medium and small mining require the location of

equipment, machinery and personnel inside a mine. This is important for reasons of safety, location and optimization of time during the excavation processes and transport of the material to the surface, as does large-scale mining.

In the implementation of a wireless network, the main problem is how the mine makes its way through the territory. Sink type mines are made up of tunnel networks, this means that wireless signals have to face many physical obstacles, making their communication range very limited. This leaves us with a second option, a wired network throughout the mine.

The technology that makes this solution possible is called Power Line Communication (PLC). This technology uses Frequency Shift Keying (FSK) to transmit digital data using the 220 VAC and 60 Hz signal as the carrier signal [5]. Figure 1 shows the connections of a PLC Network.

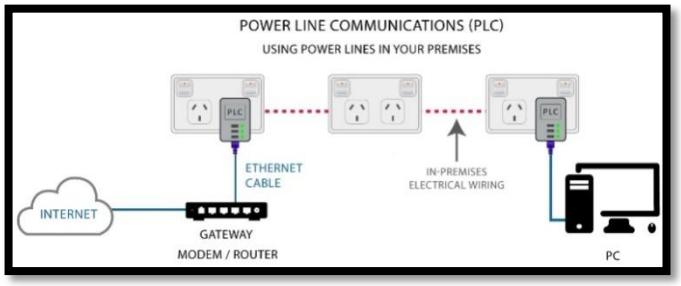

Fig. 1 Red PLC simple

II. Materials and methods

System Description

Another equally important point is the way of detecting personnel and machinery once the network is assembled. This was carried out with the use of Radio Frequency Identification (RFID) technology [2], [12], [13]. It is a technology of wireless capture and automatic identification of data. Uses radio waves to identify information contained in electronic tags: tags [4], [8]. Figure 2 illustrates the above

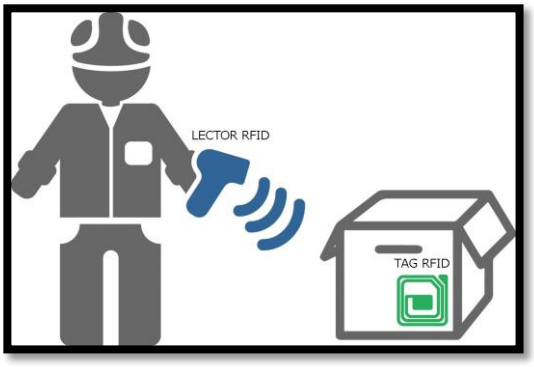

Fig. 2 Descripción del RFID

For antenna control and RFID tag detection, a digital system called a microcontroller is used. The function of this device in maintaining permanent communication with the antenna to know if an RFID tag is within its coverage range, once the presence of an RFID tag is detected, the microcontroller will proceed to read its ID and transmit it serially to the PLC circuit, which is in charge of adapting the data to the electrical network using modulation of the FSK type [6], [8], [10], [11], [14] - [16].

System design

Hardware

To start with the implementation of this system, the following elements were available:

- UHF RFID antenna
- Antenna mount
- PLC modulator / demodulator
- 8 bit microcontroller
- USB serial interface
- SOC mini PC
- Different models of TAGs
- Various electronic components.
- 220v AC power lines
- Custom made printed circuits

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

Then we proceeded to design the circuit and make the first prototypes of printed circuits (PCBs) where the antenna control circuit and transmission to the electrical network would be placed. These circuits should be installed one for each detection point within the underground mine (see Fig. 3)

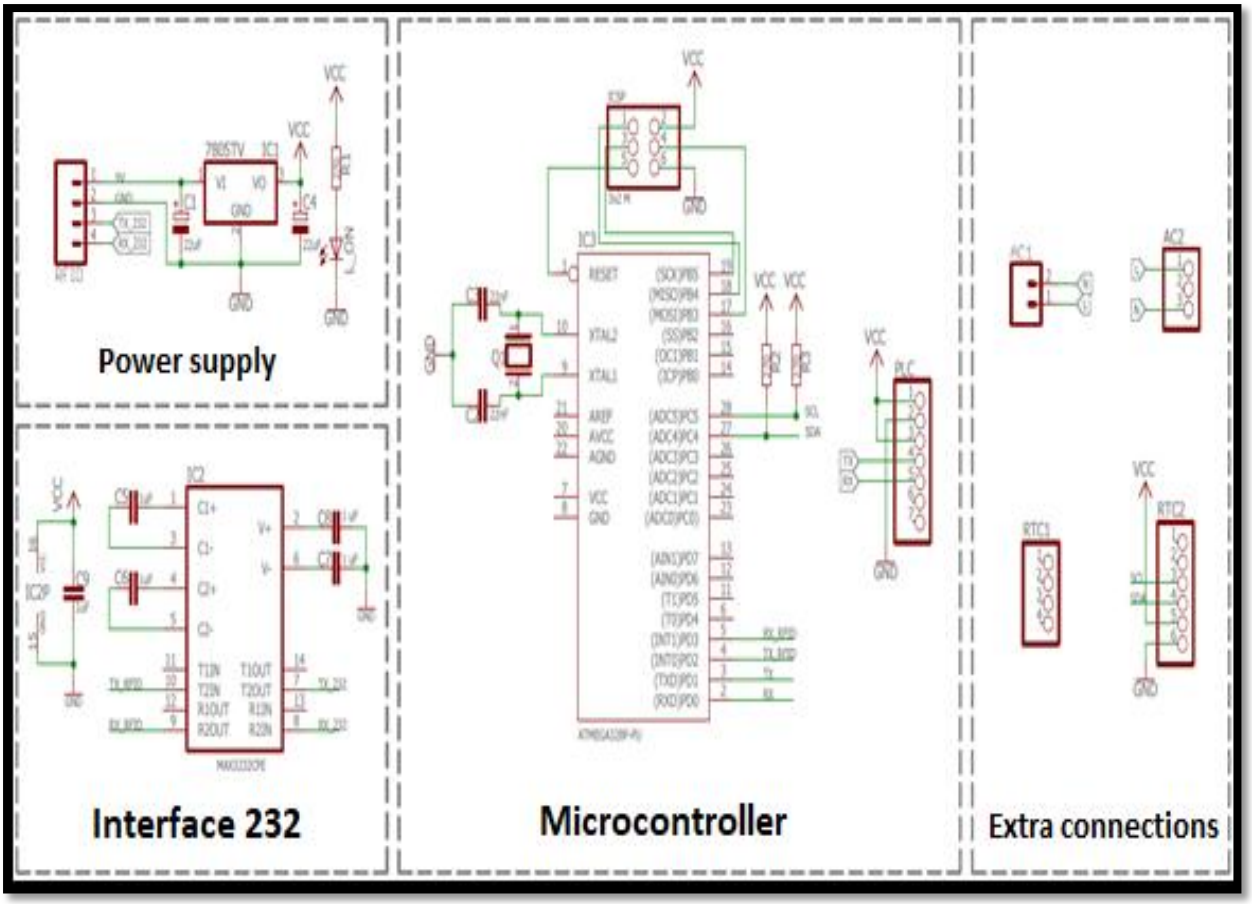

Fig. 3 Full schematic interface circuit

Tests were performed with the PLC to determine the range of transmission of the data via the electrical network and to determine the presence of possible noise in the communication that may distort the data [3]. This is important in determining what would be the maximum distance between UHF RFID antennas inside a mine.

Figure 5 schematically shows the connections necessary to carry out the communication between a uC and a minicomputer through the electrical network.

The connections between the microcontroller and its respective PLC module are made directly since both communicate by UART with TTL voltage levels; however, the connection between the PC and the PLC module cannot be direct since the PC does not have external UART ports so an interface is necessary.

The interface is implemented through a FTDI module, UART-USB interface, which allows the PLC module and the PC to communicate.

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

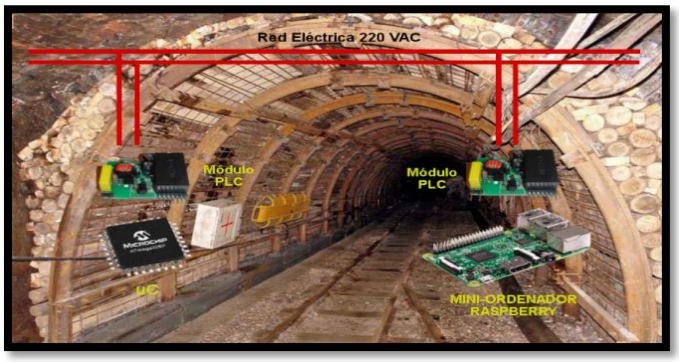

Fig. 4 Connection diagram between uC and PC

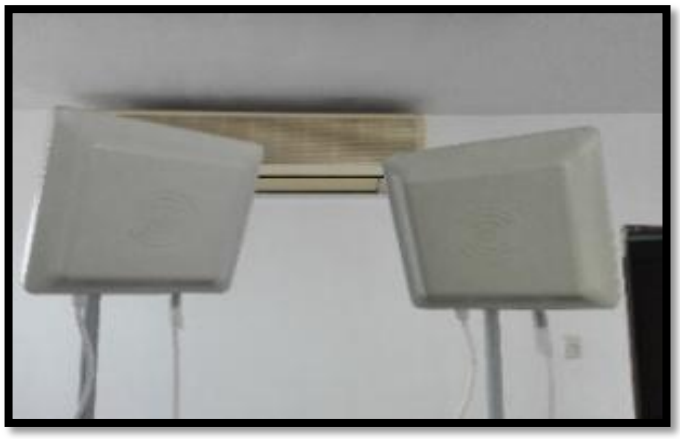

Fig. 5 RFID antennas

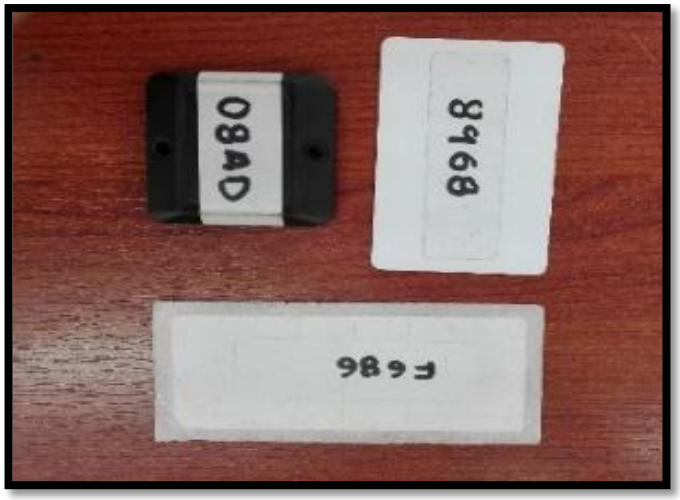

Fig. 6 Tags RFID

The cost of laying the communications network was reduced to a minimum by using existing infrastructure at the mine. This was thanks to the use of PLC modules which allowed us to transmit data through the electrical network.

A compact interface circuit designed to control, process, and store data from an RFID antenna was designed. This circuit also responds to commands sent by a minicomputer located outside the mine.

In addition, a circuit capable of monitoring the antenna network from the outside was installed, with the only connection being a power cable which must be connected to the electrical network used as the communications network, as shown in Fig. 7.

Fig. 7 Antenna network monitoring circuit

Like the monitoring circuit, the antenna-interface subsystem has a single connection, its power connection, making the installation of the antennas simple and fast (see Fig. 8).

Fig. 8 Interface circuit coupled to the RFID antenna

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

Software

Three types of software were designed which are responsible for making the entire system work:

- Antenna interface circuit software
- Computer application software
- Graphic web application software.

Antenna interface

The function of the microcontroller is to act as an intermediary between the antenna, in charge of detecting the tags that are within its scanning range, and the computer, in charge of sending the captured tags and their respective parameters to the cloud. For this purpose, a software in C programming language was developed, the flowchart of which is shown in Fig. 9.

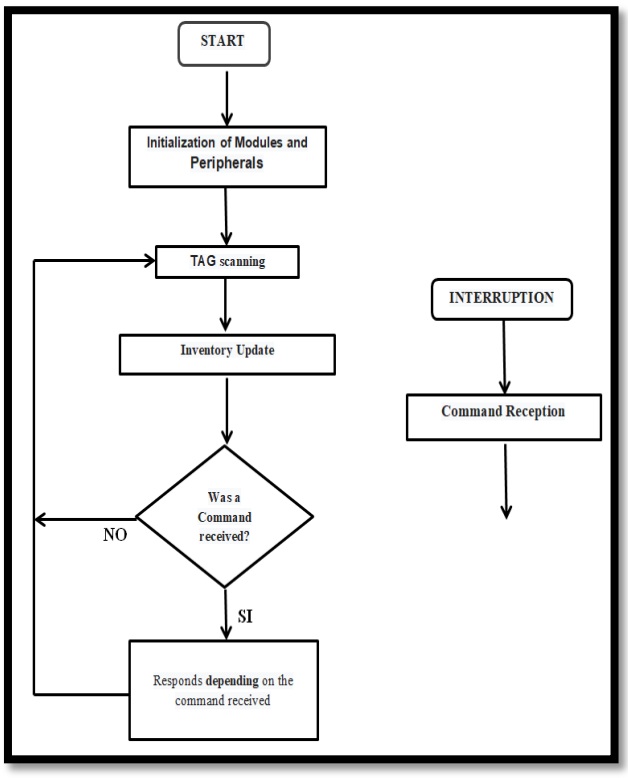

Fig. 9 Simplified flow chart of the code used in the antenna interface

The computer, or PC, is in charge of directing the entire system. This will read the inventories of all the antennas, one at a time, and export them to the server so that later a web service can use this data. Fig. 14 shows the flow chart of the application implemented to fulfill this function.

Computer application

The computer, or PC, is in charge of directing the entire system. This will read the inventories of all the antennas, one at a time, and export them to the server so that later a web service can use this data. Fig. 10 shows the flow chart of the application implemented to fulfill this function.

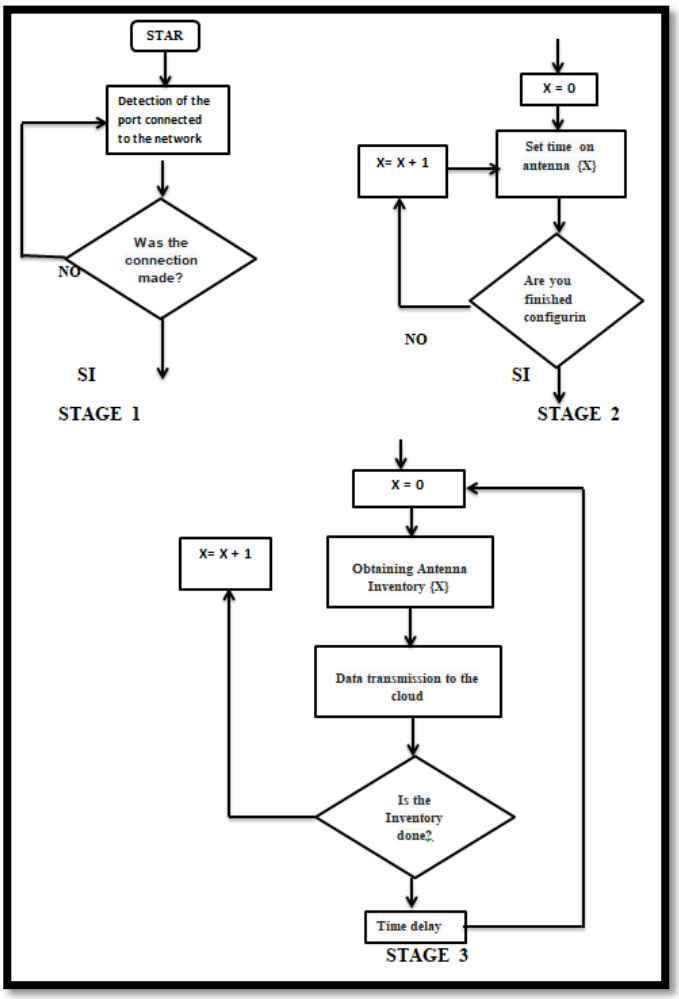

Fig. 10 Computer Application Flow Diagram

The design of this application consisted of sending data to a server, which is made up of:

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

AntenaID, TagID, Tag and Date. This format was later used in the final tests of the project. Another detail that was taken into account is the use of the same computer as a web server.

Graphic web application

Next, the construction of a web page installed in an embedded system (miniPC) was carried out, which is responsible for receiving the data from the antennas for their publication on the web and their display by people interested in this information, which It has 3 types of search: search by date, search by antenna ID and search by tag ID.

Fig. 11 shows the image of the web application developed for the project, which is used to view the inventories exported to the cloud by the computer application. In this image we see that the type of search selected is by date, which corresponds to the data exported on November 27, 2017.

Fig. 11 Web Application

III. Results

Results of the RFID tag monitoring stage

The system that best suits ours is the ARPT (Active Reader Passive Tag) system. The antenna and UHF reader are integrated into the ZK-RFID 101 antenna. This antenna feeds passive tags that are in range and the tags send a response as long as a request from the antenna has been made. To carry out the tests in the ARPT system, a software provided by the antenna manufacturer, Shenzhen ZKHY Technology Co (see Fig. 12) was used.

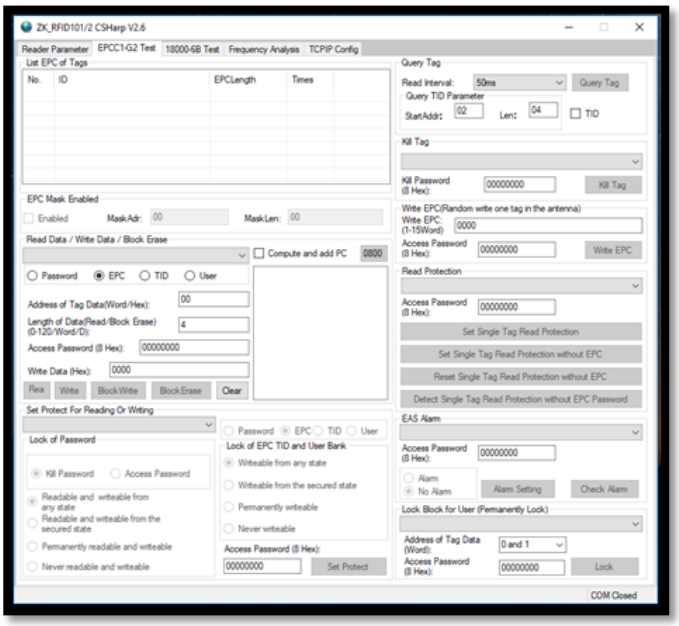

Fig. 12Scanning software provided by Shenzhen ZKHY Technology Co.

Figure13. Shows the data obtained after consecutively sampling the number of tags that the antenna can detect at variable distances. While Table 2 shows a summary of Table 1, where the effectiveness of the antenna at variable distances is calculated. For the tests, a fixed amount of 3 tags was used.

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

Distance between antenna and tags in meters	Number of tags available	Number of tags detected
0	3	3
0	3	3
0	3	3
0	3	3
0	3	3
0.5	3	3
0.5	3	3
0.5	3	3
0.5	3	3
0.5	3	3
1	3	3
1	3	3
1	3	3
1	3	3
1	3	3
1.5	3	3
1.5	3	3
1.5	3	2
1.5	3	2
1.5	3	3
2	3	3
2	3	2
2	3	3
2	3	3
2	3	3

Fig. 13 Data obtained with the manufacturer's software

Distance between antenna and tags in meters	Number of tags available	Effectiveness in percentage (%)
0	3	100
0.5	3	100
1	3	100
1.5	3	86.6
2	3	93.3

Fig. 14Cash obtained from the above data

Results of the computer application stage

For the visualization of the data uploaded to the "server" we use the DB Browser for SQLite interface, a software that allows us to visualize and manipulate data located on a certain server. The results of the data transmission can be seen in Fig. 13.

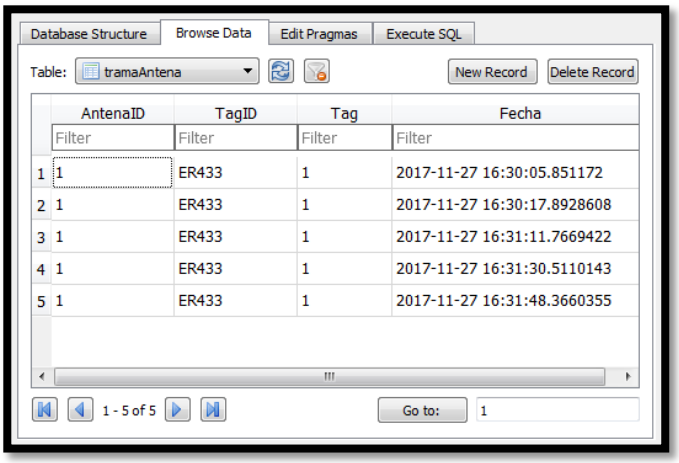

Fig. 15Data visualized in SQLite

Graphical web application results

Figures 16 to 18 show the results of the web design corresponding to the tag viewer by date, tag viewer by antenna ID, and tag viewer by tag ID, respectively

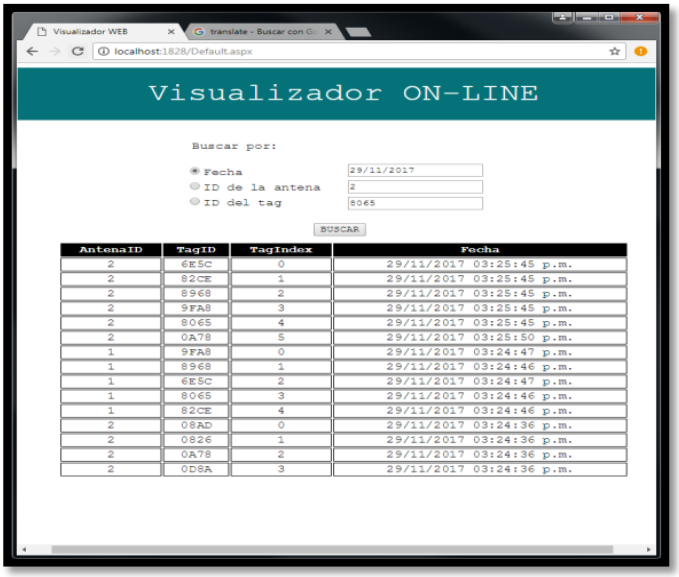

Fig. 16Web Application - Tag viewer by Date

May-June2020
ISSN: 0193-4120Page No. 24500 – 24508

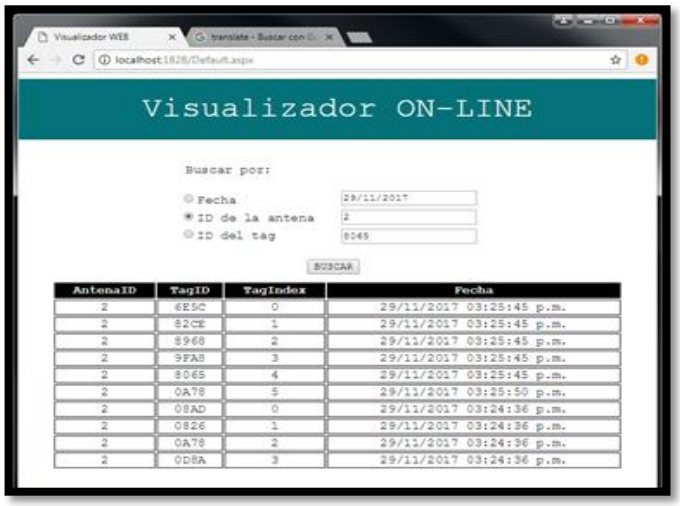

Fig. 17Web Application - Tag viewer by antenna ID

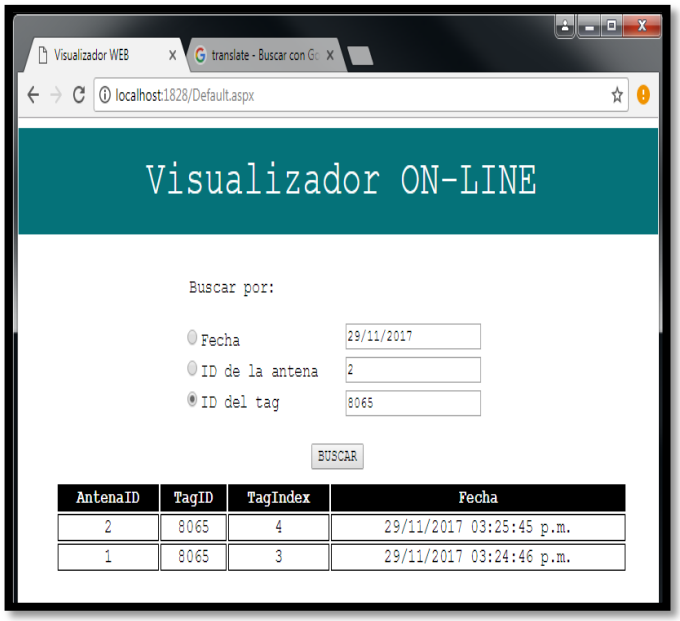

Fig. 18Web Application - Tag viewer by tag ID

IV. Conclusion

From the results shown, the following conclusions can be noted:

- A low-cost vehicle and people monitoring system can be implemented inside an underground mine, as a technological solution for medium and small mining in Peru.
- The joint work of RFID tags and antennas fulfills its function correctly, by making it possible to monitor personnel and machinery within the mine.
- The electronic design covers the system requirements perfectly.
- The software embedded in the microcontroller guarantees the continuous detection of the tags that are in its field of vision; and, in the same way, it guarantees the detection of requests by the minicomputer thanks to its interruption system.
- The electrical network is used efficiently as a communication network, thanks to the PLC modules and the software integrated throughout the system.
- The export of data to the cloud by the minicomputer is totally effective.

Conflicts of Interest

The authors declare no conflict of interest.

REFERENCES

[1] Acero, T. Costos por accidentes de trabajo en la Minería Peruana (1994-1998). Lima. 2004.

[2] Clarinox Technology. Real Time Location Systems. 2009.

[3] Cooper, D., & Jeans, T. Narrowband, low data rate communications on the low-voltage mains in the CENELEC frequencies. I. Noise and attenuation. IEEE Transactions on Power Delivery (Volume: 17 , Issue: 3 , Jul 2002).

[4] Dobkin, D. The RFID in RFID: Passive UHF RFID In Practice. eBook ISBN: 9780123948304. Newnes. 2012.

[5] Dostert, K. M. (s.f.). Telecommunication over the Power Distribution Grid - Possibilities and Limitations.

[6] Himanshu Bhatt, B. RFID essentials. O'Reilly Media. 2009.

[7] MINEM. Acidentes Mortales 2017. Obtenido de minem: http://www.minem.gob.pe/_estadistica.php?idSector=1&idEstadistica=11151. 2017.

[8] O'Connor, C. Gen 2 EPC Protocol Approved as ISO 18000-6C. RFID Journal. 2006.

[9] OSINERGMIN. ¿Cómo se clasifica la actividad minera en el Perú? Obtenido de Osinergmin: http://www.osinergmin.gob.pe/mineria/actividad_minera/clasificacion-minera-peru. 2017.

[10] Roberti, M. A 5-Cent Breakthrough. RFID Journal. 2006.

[11] Sen, D., Sen, P., & Das, A. RFID for Energy and Utility. 2009.

[12] Stockman, H. Communication by Means of Reflected Power. Proceedings of the IRE 1948.

[13] Vacca, J. Computer and information security handbook. eBook ISBN: 9780128039298. Morgan Kaufmann. 2017.

[14] Wikipedia. Power-line communication. Recuperado el 5 de Diciembre de 2017, de Wikipedia: https://en.wikipedia.org/wiki/Power-line_communication.

[15] Wikipedia. Radio-frecuency identification. Recuperado el 5 de Diciembre de 2017, de Wikipedia: https://en.wikipedia.org/wiki/Radio-frequency_identification.

[16] Wikipedia. Web server. Recuperado el 5 de Diciembre de 2017, de Wikipedia: https://en.wikipedia.org/wiki/Web_server