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RADIO FREQUENCY IDENTIFICATION SYSTEM APPLIED TO THE TRACKING AND IDENTIFICATION OF WOODEN POLES IN SERVICE IN ELECTRICAL POWER NETWORKS

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Abstract: This work presents an alternative method to track and identify utility poles used in transmission and distribution electrical power networks. The alternative method is based on radio frequency identification devices (RFID), in which electronic identification transponder tags were installed hidden inside the poles and the reading was done by a portable computer. Tests to prove the effectiveness of this technology were carried out in laboratory, before the chemical treatment process of the wooden pole, and in the energy line. The RFID showed a resistance to the autoclave treatment and a discrete look when in service. The RFID tags are an affordable and effective way to prevent the electrical energy interruption, by registering the time of service and the preservation condition of the pole.

Keywords: RFID; wooden pole identification; electrical power networks.

1 INTRODUCTION

In Brazil, poles made of eucalyptus species are used in electrical transmission and distribution lines. The poles are identified by data recorded on a metallic plate attached to the wood with nails. The number engraved on the metallic plates indicates the origin and manufacture dates, the eucalyptus species, the chemical product and the treatment used in the pole confection. The identification data are used to manage the in service pole inspection times and it is in service time in the electricity grid (VIDOR, 2011).

Eucalyptus woods have several physical and mechanical properties that may differ among species, such as apparent density, bending strength, modulus of elasticity and modulus of

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rupture, as well as the degradation process resistance caused by biological attack (TREVISAN et al., 2007).

Therefore, the pole data input is an important tool for the eucalyptus wood conservation, preventing power interruption as well as accidents involving the electricity grid. The main inconvenience of the metallic plates is human depredation and environmental degradation through the years (VIDOR, 2011). The use of the commercially available radio frequency identification (RFID) was proposed to suppress the deficiencies of the current identification system.

An RFID identification system operates in a manner analogous to a barcode reader, in which the information is saved on a label and recovered by an optical reading process. From there, a computer connected to the reading system retrieves the data and compares them with a database where detailed information about the product is stored. The great advantage of these systems is the fact that this pattern enables encoding in environments which are harsh or exposed to weathering. This system allows reading the label hidden in side boxes or the object itself to be identified (ARRUDA, 2006).

The RFID system is a technology, which is an increasingly being employed to tag and identify objects. The use of RFID systems was motivated by their net safety, low employment cost, and accuracy. The RFID systems have two types of components: RFID transponders (tag) and RFID transceivers (tag readers) (FINKENZELLER, 2003). The transponder contains at least an integrated circuit (IC) and an antenna. The operation of RFID is remote; when a tag senses wireless radio frequency (RF) waves from the reader, the control circuit inside the tag transfers the energy of the wireless waves into internal power. Tags store information using a small integrated circuit and communicate with the RFID reader using an antenna (CARBURAR et al., 2009).

The RFID readers are capable of reading the information stored on tags including a number or electronic product code (EPC). Most tags are passive, i.e., they do not require battery power, once passive tags use the energy of the reader’s signal to fetch, process, and communicate with stored data. Passive tags do not need maintenance; they have limitless in service time (TZENG et al., 2008).

The aim of this study was to test a safer alternative form of identification and tracking of wood poles in electricity distribution lines. To achieve this, three experiments were performed using a RFID system. In the first experiment, tests were carried out in laboratory to evaluate the best positioning for the tags and the stick antenna reader in relation to the angle and to the reading distance when inserted inside the wood. In the second experiment, the mechanical and chemical resistance of the tag were tested when it was exposed to the pressure (from wood swelling and shrinkage) that takes place during the treatment process. Finally, tags were inserted in traceable poles in the urban line distribution. In a two-year period, the devices were tracked and analyzed during the inspection visits.

2 MATERIAL AND METHODS

The low frequency (LF) RFID system, operating in a frequency of 125±6 kHz – which allows detection in a range of less than 0.5 m – and passive SAMPT (RI-TRP-IR2B) tags, glass encapsulated, with 4.0 mm of diameter and length of 32 mm, were used in all experiments.

The short-range devices with operation frequency close to 126 kHz significantly decrease the chance of interference from other devices. The electromagnetic waves generated in this case were within the safe bandwidth limit allowed by resolution nº 365 of the Telecommunications National Agency of Brazil – ANATEL (2006) as also, the Federal Communications Commission (FCC) and the European Telecommunications Standards Institute (ETSI) (TZENG et al., 2008).

The tags were inserted manually in an orifice of 4.5 mm of diameter and 50 mm of length, made with a drill, with the antenna pointing outwards the pole. Afterwards, the puncture was covered with epoxy resin to hide the device in the wood. A tag identifies a pole with a single associating number, with 64 bits. The number is related to the information registered in the database of the power company.

The stick antenna (RI-ANT-S01C) was used along with the TEXAS RFID reader “S2000 Reader” (RISTU-MB2A) in laboratory tests to help handling during the tests. For the *in situ* tests, a portable data acquisition system (PDA), the 134 kHz “Rugged Handheld DI-400 RFID” model, was used to store data and transmit the information collected to the company’s database.

The read data were processed with the DI-400 of the Personal Development Kit software supplied by the TEXAS Company, customized with the Microsoft - Embedded Visual C++ version 4.0.

2.1 Position test

A new pole was cut from a 300 mm long section to be used for a series of tests. A tag was inserted in the pole section according to the previously described method and the stick antenna reader was used according to the manufacturer’s instructions. The aim of the experiment in laboratory was to identify in which position the tag offered a most favorable recognition. Figure

2 shows the positions of the tag (inside the pole) and the stick antenna reader in the tests. In Figure 1, the two tests are shown; in 1a, the antenna reader is positioned at 90° from the tag, and in 1b, the antenna reader aims at 0° from the tag.

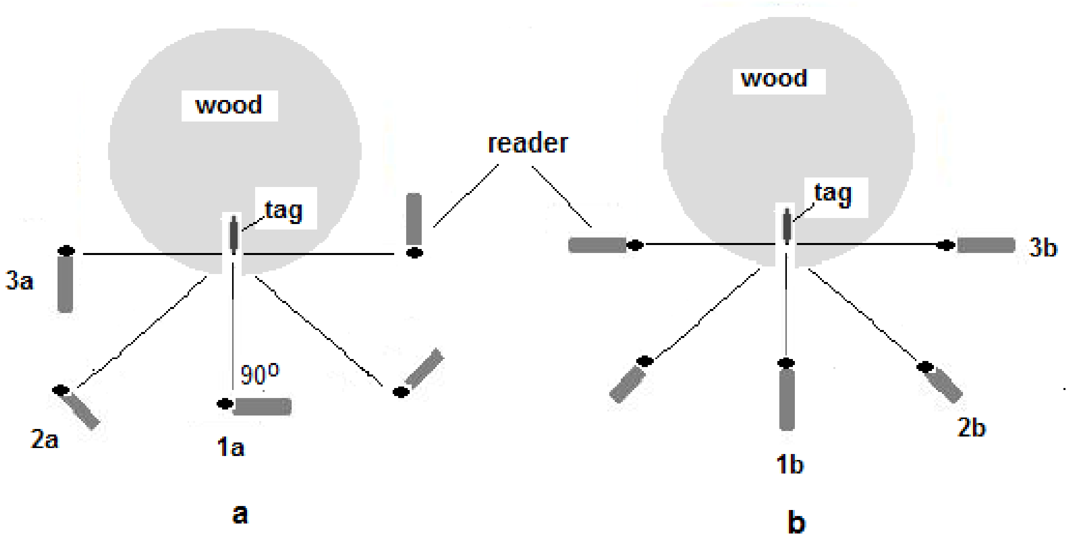


Figure 1. Crossed alignment: The tag and the stick antenna reader are at 90° from each other (a); Parallel alignment: the tag and the stick antenna reader are at 0° from each other (b).
Figura 1. Em a) Alinhamento cruzado: A etiqueta e a antena do leitor estão a 90° um do outro (a); Alinhado paralelamente: a etiqueta e a antena do leitor estão a 0° um do outro (b).

The experiments were carried out with the antenna operation at minimum tension (361V) and with a stationary antenna reader set over a desk. The antenna reader was placed at 70 mm of distance, at relative angles of 0° (1a and 1b), 45° (2a and 2b), and 90° (3a and 3b) from the tags, respectively.

To identify the maximum recognition capacity of the stick antenna reader (100%) when the tag is inside or outside the pole, the reader was dragged from the initial position of 140 mm distance (every 10 mm) towards the pole, in 0, 30, 60 and 90° angles (as shown in Figure 2) until reaching the wood surface.

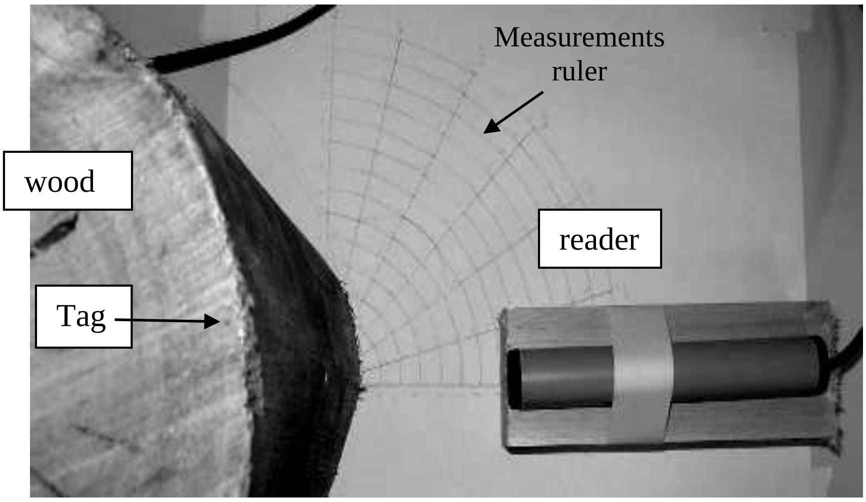


Figure 2. Test to identify the maximum capacity of the stick antenna reader.
Figura 2. Teste para identificar a capacidade máxima da antena do leitor.

2.2 The autoclave test

In the second experiment, nine new eucalyptus poles had the identification tags inserted into them and the insert hole covered with an epoxy resin to keep the tags stuck in the wood for the resistance tests during the manufacturing process, as shown in Figure 3a. These poles were chemically treated in autoclave with chromated copper arsenate (CCA), a material currently used in Brazil, and aiming at the wood chemical preservation treatment with CCA, the poles were put in an autoclave, Figure 3b. The CCA impregnation process takes approximately 3 hours to reach the sapwood, Figure 3c.

After the test, the poles were placed outdoors to dry. The epoxy resin covers were not damaged during the process, and the tags were able to respond to the identification reading, Figure 3d.

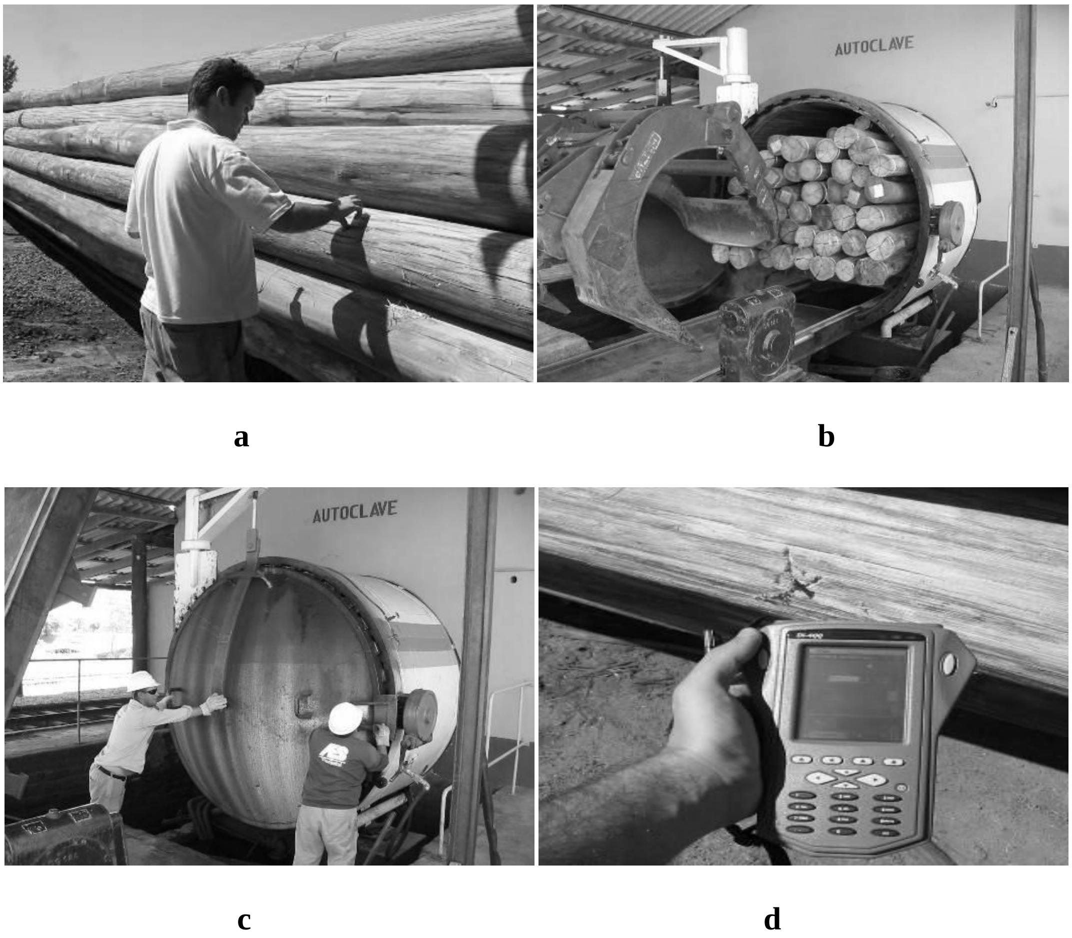


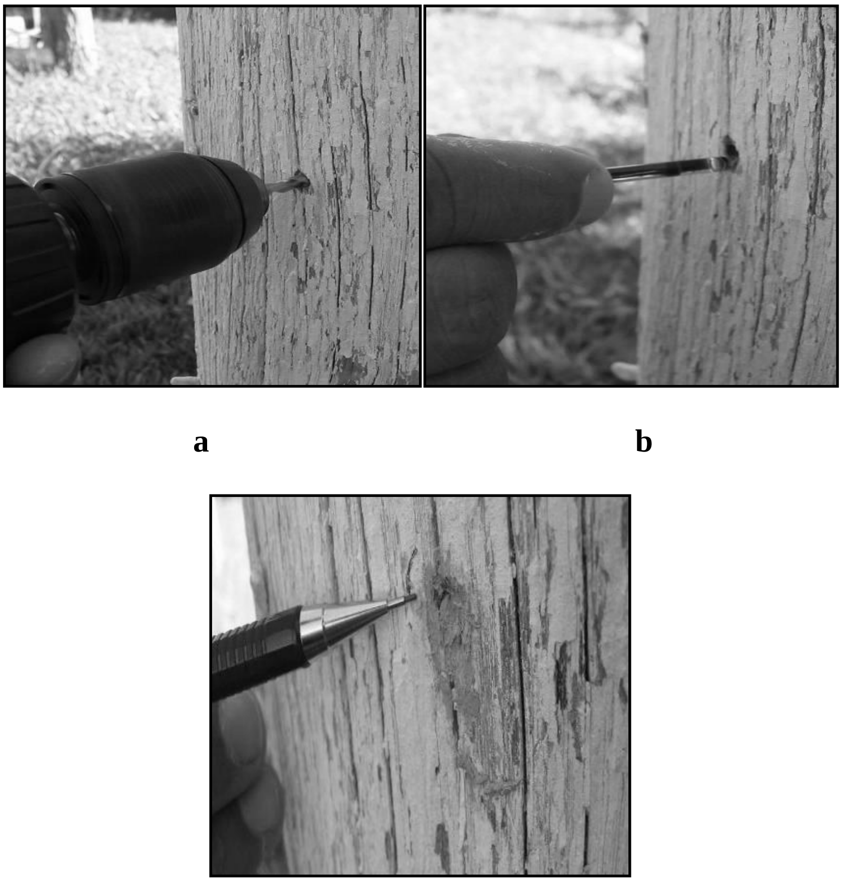
Figure 3. Mechanical and chemical resistance of the tags in the autoclave treatment test. a) Insertion of tags into the poles, b) Poles in the autoclave, c) Beginning of treatment and d) Reading.
Figura 3. Resistência mecânica e química da etiqueta no teste de tratamento em autoclave. a) Aplicação das etiquetas dentro dos postes, b) Postes na autoclave, c) Início do tratamento e d) Leitura.

2.3 Inspection test

Aiming at determining the possible signal interference between the tag and the PDA reader by metallic elements in the power line as well as by induced magnetic fields, ten tags were installed in the in service poles 1 m above the ground line.

In the inspection practices (VIDOR et al., 2010), working ergonomic issues and the reading system adaptation were considered to install the tag in the pole, following the protocol: 1) Perforate the pole one meter above the ground line perpendicularly to the energy line, facing the road (when possible); 2) 50 mm perforation with a 4.5 mm wood drill; 3) Insert the tag in the hole with the antenna pointing outwards the pole and 4) Cover the hole with epoxy resin.

Figure 4 (a, b and c) illustrates the methodology used to apply the tags into in service wooden poles. The data read by the PDA were transmitted to and received by the company’s database. In a two-year period, the devices were tracked and analyzed during the inspection visits.



a b

c

Figure 4. Sequence of installation of electronic tags into in service wooden pole.
Figura 4. Sequência de instalação das etiquetas eletrônicas no poste de madeira em serviço.

In an inspection of wooden poles described by Vidor et al. (2010) the process was conducted in twenty cities in southern Brazil since 2002, the amount of poles that had the nameplate as well as the loss of those nameplates in the course of eight years of study was evaluated.

3 RESULTS AND DISCUSSION

The profile of the reading signal obtained in the first experiments with the tag inside and outside the pole showed that a signal attenuation of approximately 15% of the maximum occurs when the tag reader is approximately at a 90^0 angle from the tag inside the wood (Figure 5b) when compared with the tag outside the wood (Figure 5c). The increase in the wood mass intercalated between the reader and the tag is what probably interferes in the signal. A similar attenuation was observed in previous tests in position 3b, showed in Figure 1.

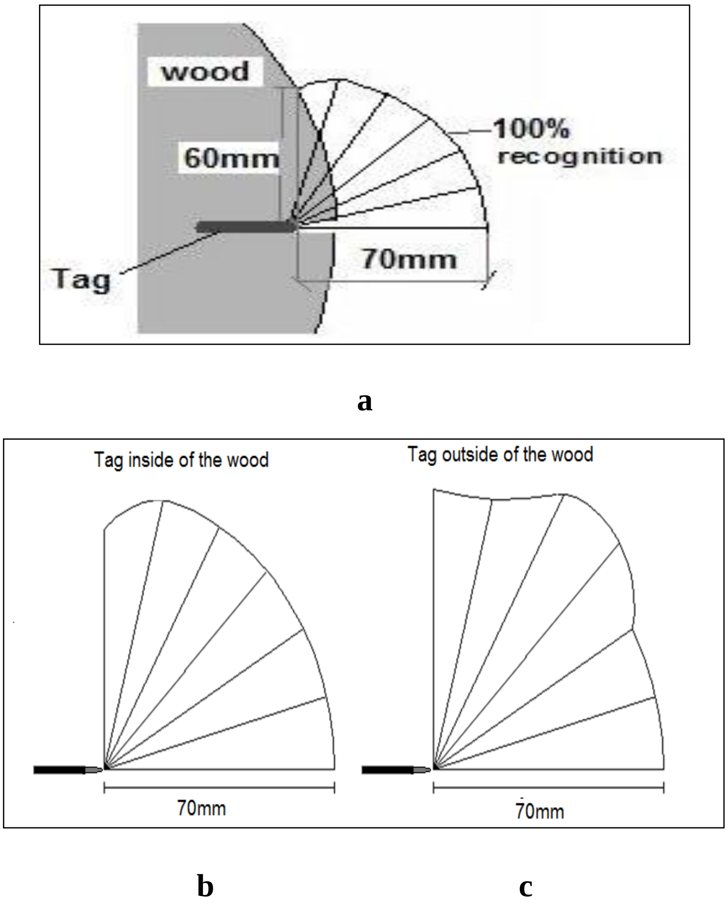


Figure 5. a) Maximum recognized volumes of stick antenna reader for 100% tag signal; b) Tag inside the eucalyptus pole; c) Tag outside the eucalyptus pole.
Figura 5. a) Área máxima de reconhecimento do leitor da antena para o sinal da etiqueta 100%, b) Etiqueta dentro do poste de eucalipto; c) Etiqueta fora do poste de eucalipto.

Consequently, the tag reader operator must be near the pole during the pole inspection. The experiments demonstrated that a 70 mm minimum distance is adequate for the tag number reading in the eucalyptus poles to occur with precision. However, the reading distance can be increased by varying the power given to the stick reader antenna up to 450 mm, according to the Texas Instruments' Manual (2005). The power increase represents higher power consumption by the portable device, that is, it means lower autonomy by the reader antenna.

After the pole chemical treatment, four wooden poles were opened with the appropriate tools in order to examine the physical integrity of the tags. All tags were in perfect working condition, without any fractures or chemical damage, which indicates that the RFID system can be adopted since the tree cutting.

According to Arruda (2006), the lack of identification plates on the poles causes damage in service, in that it loses all trace of the poles. Without identification, it is not possible to know the origin, species, time in service, treatment and retreatment, among other data, which are important for network maintenance.

It was noted that during a pole inspection and re-inspection program conducted since 2002 in twenty cities in southern Brazil, as presented in Figure 6 (which presents the identification plate facts of the poles in exam of reinspection performed in the period of 2008-2010), from a total of 8,608 inspected wooden poles, 3,115 possessed identification plates, which corresponds to 36.2% of the total. With regard to the number of poles with identification plates, only two cities presented a percentage of poles with plates above 50%. In comparison with the total, the poles with identification plates had decreased to a general average of 2% comparing with the inspections carried on the same poles in the period of 2004-2006 (Figure 7).

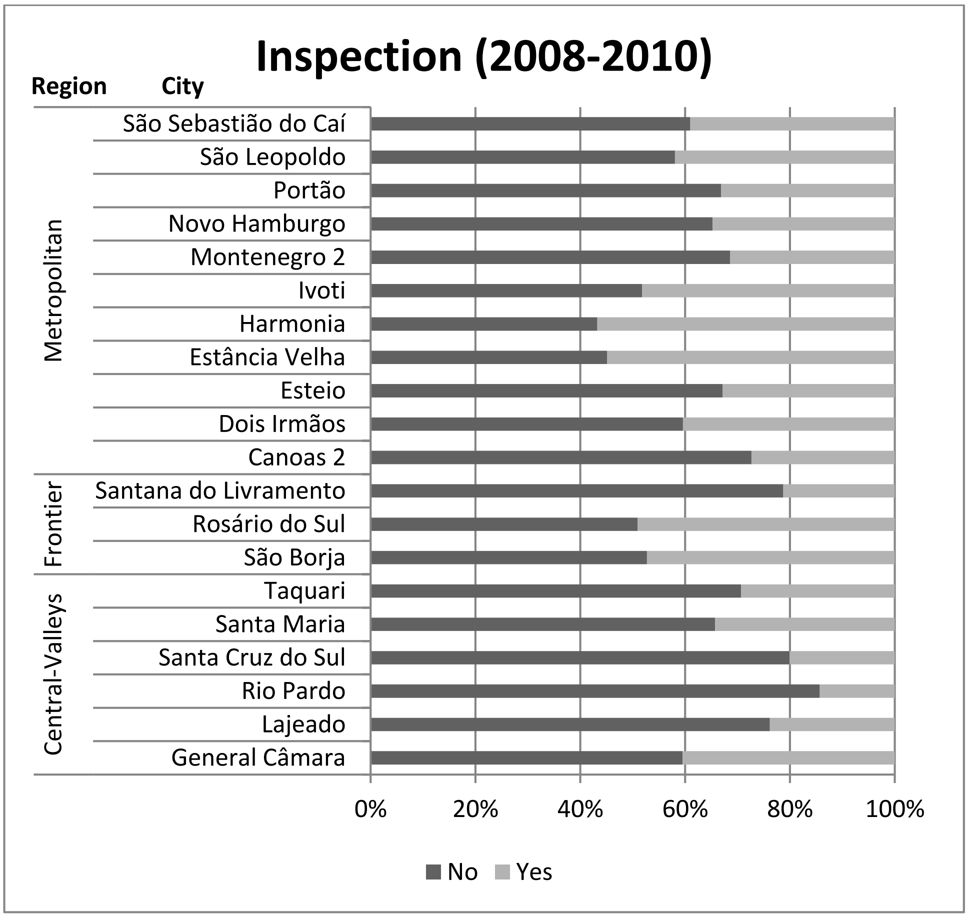


Figure 6. Incidence of identification tag on wood poles in the Rio Grande do Sul urban region (inspection 2008-2010) (south of Brazil).

Figura 6. Incidência das placas de identificação em postes de madeira no Rio Grande do Sul, região urbana (inspeção 2008-2010) (sul do Brasil).

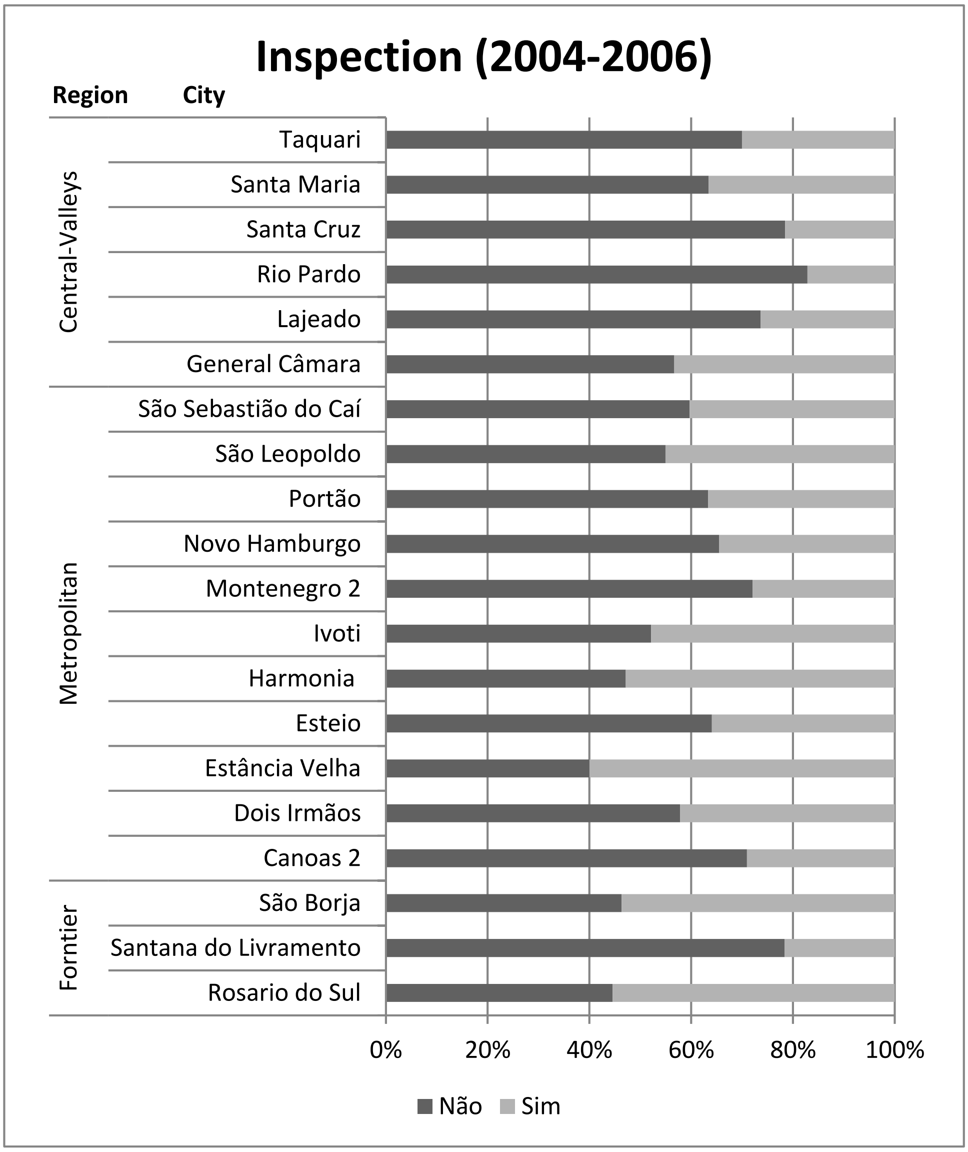


Figure 7. Incidence of identification tag on wood poles in the Rio Grande do Sul urban region (inspection 2004-2006) (south of Brazil).
Figura 7. Incidência das placas de identificação em postes de madeira no Rio Grande do Sul, região urbana (inspeção 2004-2006) (sul do Brasil).

Figure 8 presents the data regarding plates of identification of poles under examination of reinspection performed in the period of 2008-2010 in two cities with a bigger period of accompaniment. A total of 463 inspected wooden poles, 162 possessed identification plates, which corresponds to 35%. In a comparison with the total, the amount of poles with identification plate had decreased to a general average of 2%, compared with the inspections carried on the same poles in the period of 2002-2003 (Figure 9).

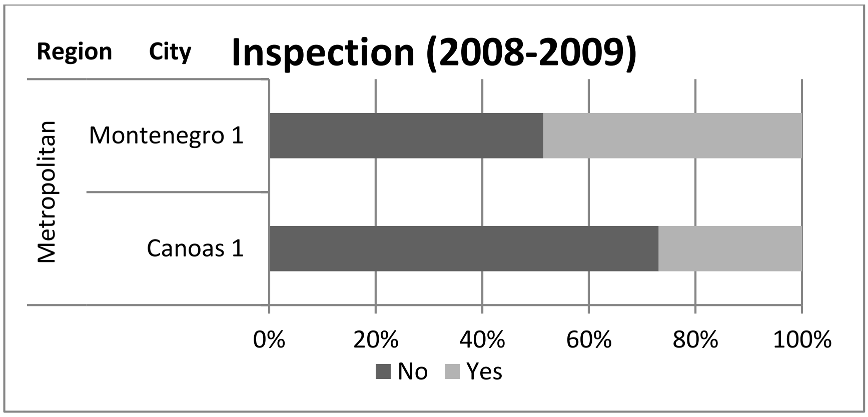


Figure 8. Incidence of identification tag on wood poles in the Rio Grande do Sul urban region (reinspection 2008-2010) (south of Brazil).
Figura 8. Incidência das placas de identificação em postes de madeira no Rio Grande do Sul, região urbana (reinspeção 2008-2010) (sul do Brasil).

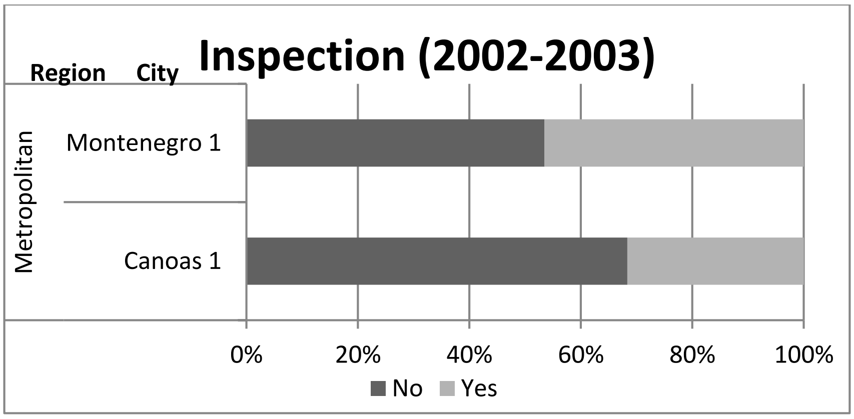


Figure 9. Incidence of identification tag on wood poles in the Rio Grande do Sul urban region (reinspection 2002-2003) (south of Brazil).
Figura 9. Incidência das placas de identificação em postes de madeira no Rio Grande do Sul, região urbana (reinspeção 2002-2003) (sul do Brasil).

In Brazil, poles with 15 years in service in electrical power distribution networks must be replaced as required by law however, poles without identification can only be replaced after a diagnosis of advanced biological degradation or by accident, when the disruption of energy would be inevitable. The high annual replacement of wood poles observed during the inspections from 2003 to 2010 was caused by some of reasons described previously (VIDOR, 2011).

Electronic tags installed in the energy net poles in the urban area were monitored for six years and none of them was damaged, lost, nor taken out of the pole. This demonstrates that the use of the RFID technology for pole identification was considered suitable for conservation status control.

Even treated, certain species of eucalyptus have an accelerated decrease in their condition associated with negligence both during the manufacturing process and in the selection of species of eucalyptus (VIDOR et al., 2010). The data stored in this system could be used to supplement the data from the inspection procedure presented by Vidor et al. (2009).

Therefore, the identification electronic tags can help to carry out an efficient program for the maintenance of the net, estimating the useful life of poles and preventing accidents, as well as for the management of the eucalyptus species forests. It is a new technology considering its application in poles and its use can be extended: electronic tags can be introduced in the wood before the manufacturing process of the pole and even in young trees, enabling full traceability of the product. Due to the passive tag's reduced dimensions, which occupies only a small area in the internal part of the tree, the presence of the device does not harm the development of the plant. The correct management of wood natural resources allows the conservation of forests and, therefore, it contributes to the preservation of the environment (HOYT et al., 2003).

4 CONCLUSIONS

The electronic identification transponder tag by radio frequency identification (RFID) is a safe option to identify and track power line poles. The passive tag is easily applied inside the wooden pole. The electronic glass encapsulated tag proved to be suitable for application before the chemical preservation process of the pole. The difficult visual identification of the device when installed inside the wood inhibited human depredation and environmental degradation.

Therefore, without the identification tags it becomes impossible to carry out an efficient program for the maintenance of the net to estimate the useful life of poles and to prevent accidents.

5 ACKNOWLEDGEMENTS

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