Inspection of Wooden Poles in Electrical Power Distribution Networks in Southern Brazil

Flávio L. R. Vidor, Marçal Pires, Berenice A. Dedavid, Pedro D. B. Montani, and Adriano Gabiatti

***Abstract*—This work aims to test an inspection method for wooden utility poles based on a classification system according to qualitative (visual and sounding) and quantitative parameters (excavation and drilling) to assess internal/external wood decay. Ten thousand poles were inspected, distributed over 23 cities in the state of Rio Grande do Sul (Southern Brazil). The results indicated a significant quantity of poles in advanced decay (14%) with a great variability among cities. Poles treated with chromated copper arsenate (CCA) presented worse conservation when compared to creosote preserved poles, suggesting possible problems on CCA treatment.**

***Index Terms*—Inspection, poles and towers, power distribution maintenance.**

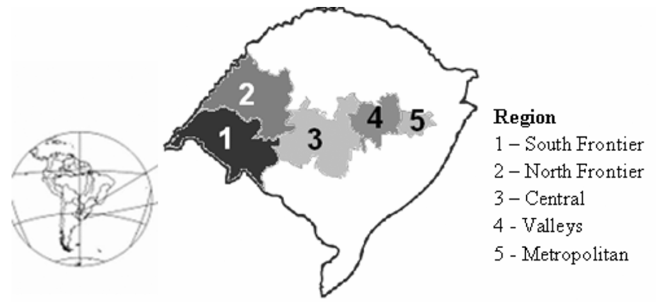

Fig. 1. Map of Rio Grande do Sul State (South Brazil) showing the five regions of the AES Sul electrical power distribution network area.

I. Introduction

THE use of wooden poles to support electrical overhead lines and the knowledge of their state of conservation become crucial for decision making by companies in the electricity sector which use these structures. It is the consensus among electricity distributors that the extension of the in service life of wooden poles represents an important factor on cost accounting. The approach given to the program of maintenance and replacement of poles can be decisive in the economic impact of these structures on power distribution systems [1]. Thus, these programs must be accompanied by a probabilistic approach that allows reduction and optimization of costs [2], [3]. Since wood is a renewable resource, the environmental gain must also be taken into account.

Wooden poles have been commonly used to support electrical lines throughout Southern Brazil, being produced from eucalyptus, an exotic species widely cultivated in the country [4]. Unfortunately wood is subject to deterioration, which can occur due to the action of physical, chemical and biological agents. Biological agents are the most important decay factor, and wooden poles can be attacked by bacteria, insects, fungi and marine drills. In Southern Brazil, special attention is given to fungi [5], organisms whose forms and lifestyles vary from simple yeast to a mushroom. The attack of wood decaying fungi can be rapid and it results in dramatic loss of pole strength [5]–[7]. Thus, the lifetime of the in service pole could be shortened due to this decay. It mostly occurs within a region extending from about 0.5 m above to 0.5 m below ground line, where the presence of oxygen and moisture ($>20\%$) enables metabolic activity and growth of aerobic micro-organisms such as fungi. There is a large number of insecticides and fungicides used in wood treatment, but the efficiency obtained in the application of these wood preservatives varies greatly [7]–[9].

The electrical networks in Rio Grande do Sul State (RS), Brazil's southernmost region, use over 2 million wooden poles to support distribution and transmission lines. The AES Sul owns the distribution of electric energy in the center-west region of RS, which is divided into five subregions (Fig. 1). The AES Sul serves approximately 950 000 consumers in 114 cities on a surface area of 99.268 km^2. In its networks, there are about 800 000 poles, of which approximately 90% are made of wood [10].

The Brazilian Standard (NBR 8456) establishes eight Eucalyptus species to be used in the pole production [11]. The most employed treatment is the one with a water-based chromated copper arsenate preservative (CCA) applied under pressure, since the use of the pentachlorophenol and creosote is forbidden. According to this standard, treated wooden poles must have a lifetime of at least 15 years. Alternative preservatives have been proposed in Brazil to substitute and/or complement CCA treatment [12], [13]. Special attention has been payed to boron/fluoride preservative used in the retreatment of in service poles [9] due to its high efficiency and lower toxicity for humans and the environment.

An increase in the in service lifetime of poles is important not only due to the costs associated with its replacement, but also because poles out of service are considered hazardous wastes which must be adequately disposed of.

This work presents a research carried out for three years with the aim at inspecting about 10 000 wooden poles, distributed over 23 cities in Southern Brazil. The main object is to establish a practical, reliable and low cost inspection procedure for in

Manuscript received December 03, 2008; revised April 29, 2009. First published December 04, 2009; current version published December 23, 2009. This work was supported by the AES Sul. Paper no. TPWRD-00878-2008.

M. Pires, F. A. Vidor, and B. Dedavid are with Pontifical Catholic University of Rio Grande do Sul (PUCRS), Porto Alegre, RS 90619-900, Brazil (e-mail: mpires@pucrs.br; flavio.sigeplan@terra.com.br; berenice@pucrs.br).

A. Gabiatti and P. Montani are with AES Sul, São Leopoldo, Brazil (e-mail: adriano.gabiatti@aes.com; pedro.montani@aes.com).

Digital Object Identifier 10.1109/TPWRD.2009.2034913

TABLE I
LOCATION AND NUMBER OF THE INSPECTED IN SERVICE POLES IN FIVE AES SUL REGIONS

Region	Number of Cities	Inspection	
		Number of Poles	%
Central	2	976	9.1
North Frontier	2	859	8.0
South Frontier	3	1,583	14.8
Metropolitan	11	5,54	51.8
Valleys	5	1,734	16.2
Total	23	10,692	100

service poles. In addition, wood samples were collected during inspections and then cultures have been developed for subsequent identification of the fungi.

II. Materials and Methods

The inspection procedures used in this work are based in several studies and standards developed in Brazil [4]–[14], and in other countries [8]–[16]. A simplified and practical method is proposed in addition to quantitative parameters in order to avoid a subjective inspector's decision.

A. Sampling

Approximately 10 000 in service poles were selected randomly from a population of 800 000 poles, located in the AES Sul area (Fig. 1). Twenty three cities, representing the five enterprise subregions (Table I), were visited by inspectors from 2002 to 2004. These cities were chosen because they present differences on soil and climatic conditions. In each city several low voltage lines were randomly sampled in urban and rural areas. The pole location was obtained by GIS maps from AES Sul.

The majority of poles (52%) were located in the highest urbanized Metropolitan region, while poles located in rural areas are predominant in the North and South Frontier regions. This pole distribution is very similar to the global AES Sul network [10].

B. Inspection Method

The pole inspection involved three steps: visual assessment, hammer test and quantitative test of decay. The visual assessment of wood surface determines the extent of defects such as cracks, holes, burned or rotten points, etc. The hammer sound test is used to detect a hollow core caused by internal decay in the pole portion from the ground line up to 2 m. The clear sound and hammer rebound confirms that the internal condition of the wood is sound [Fig. 2(a)].

As the assessment by visual inspection and hammer test is rather subjective, measurements of internal and external decay were also performed.

The external pole inspection includes digging to asses the critical region below ground line (0.5 m). A complete excavation is made, the pole is brushed to be free of dirt and its surface is examined to evaluate whether it is rotten. The surface is scraped with a shovel and all rotten wood is removed. As external decay could eventually reduce the effective circumference of the pole


(a)
(b)
(c)
(d)

Fig. 2. Steps for external (a)–(b) and internal (c)–(d) inspection of the in service poles. (a) Hammer test. (b) Digging and external inspection. (c) Drilling a hole to internal inspection. (d) A marked metal rod used to asses solid wood thickness.

[Fig. 2(c)], this parameter is measured in two different pole regions at 0.10 m above and 0.10 m below ground line. The difference in the pole circumferences is used to estimate external decay.

The internal pole decay is assessed by drilling a small hole (diameter of 12 mm) at ground line in an angle of 90° with wood surface [Fig. 2(c)]. To determine the thickness of solid wood (not necessarily sound), a probing rod adapted with a hook at the end [Fig. 2(d)] is inserted into the hole. When the rod is pulled back the hook catches on the edge of the rot pocket and the marks on the sides of the rod indicate the shell thickness of the solid wood at drilling point. The measurement is used to

TABLE II
IN SERVICE POLE INSPECTION CLASSIFICATION ACCORDING TO INTERNAL AND EXTERNAL DECAYS AND RECOMMENDED PROCEDURES

Inspection		**Class**	**Procedure**	
Internal	External		Evaluation	Action
healthy wood	rotten wood			
> 0.10 m	without	**1**	Good	none
0.07 to 0.10 m	max. 0.01 m	**2**	Initial decay	Retreat Int./Ext.
0.03 to 0.70 m	max. 0.02 m	**3**	Advanced decay	Retreat Int.
< 0.03 m	total	**4**	Failure	Replace

estimate internal decay. All inspection drilling holes are treated with a Boron/Fluoride water-diffusible preservative (PoleSaver, Preschem Australia) and plugged with a PVC dowel to prevent decay.

In Table II, a summary of inspection system is presented with quantitative decay, the proposed pole classification, based in a numerical and color scale, and recommended actions as follows.

1) (Green): pole is considered serviceable, no corrective actions suggested.
2) (Yellow): partial decay but still serviceable, an internal/external retreatment is recommended.
3) (Orange): rejected pole with an advanced decay, a rehabilitation (reinforcement/retreatement) should be made.
4) (Red): Danger, rejected pole not suitable for rehabilitation, needs immediate replacement.

In a previous study [13], the proposed inspection procedure was compared to a nondestructive evaluation technique using Polux device (CBT-France). Vidor [13] tested 200 in service poles, obtaining an excellent agreement (99.5%) between proposed inspection procedure and Polux diagnosis.

C. Reporting Data

The inspection and pole information are registered in the field, using a hand computer (Palm), on a database (Access, Microsoft). The registered pole information, contemned on a metal identification tag, includes: pole brand date (month/year), pole length and eucalyptus species, preservative type, and pole supplier. No entries were made where information could not be read on the tag or it did not exist. The inspection data registered on database are: pole location, the address and GPS coordinates (Garmin, ETrex), which is put in a map (GPS Trackmaker); decay evaluations, pole classification, and recommended action.

D. Mycological Study

The sawdust produced in the pole drilling during inspections has been collected and stored in tightly sealed plastic bags and kept under refrigeration ($\sim$10° C). The culturing of cores for decay fungi were performed in a sterile chamber with the sawdust using agar-potatoes as substrate [5]. The culturing materials were kept under controlled conditions (33° C) for about two months, being monitored weekly with an optical microscope also used for decay fungi identification.

TABLE III
INSPECTED POLE CLASSIFICATION BY CITY; THE PERCENTAGE IN URBAN AREAS, AND OF METAL TAG IDENTIFICATION

City / Region	# Poles	ID tag %	Urban %	Class (%) 1	2	3	4
Santa Maria	490	40	81	68	8	13	11
Sobradinho	419	37	68	56	16	13	14
Central	**909**	**39**	**75**	**63**	**12**	**13**	**12**
Santiago	420	48	67	58	15	12	14
São Borja	407	54	51	49	23	16	11
North Frontier	**827**	**51**	**59**	**54**	**19**	**14**	**13**
Rosario do Sul	488	56	70	37	38	18	7
S. Livramento	508	22	60	55	31	10	5
Uruguaiana	505	37	63	34	31	19	16
South Frontier	**1.501**	**38**	**64**	**42**	**33**	**16**	**9**
Canoas	442	32	100	43	29	14	14
Dois Irmãos	532	47	78	52	26	15	7
Estância Velha	439	64	100	55	25	12	8
Esteio	451	37	100	39	27	16	18
Harmonia	194	57	100	45	24	15	16
Ivoti	458	52	100	47	25	16	11
Montenegro	372	33	100	48	28	15	9
Novo Hamburgo	358	44	100	53	27	13	7
Portão	468	40	100	36	23	24	16
São Leopoldo	683	46	100	48	23	15	14
São S.Caí	257	54	100	42	22	18	19
Metropolitan	**4.654**	**45**	**97**	**46**	**25**	**16**	**12**
General Câmara	198	46	100	50	18	14	18
Lajeado	279	28	100	43	18	19	20
Rio Pardo	191	19	100	53	17	12	18
Santa Cruz	398	28	100	46	21	18	15
Taquari	289	31	100	43	21	17	19
Valleys	**1.355**	**30**	**100**	**46**	**19**	**16**	**18**
Total	**9.246**	**42**	**87**	**48**	**24**	**15**	**13**

III. RESULTS AND DISCUSSIONS

Among the 10 692 inspected poles, distributed over five AES Sul regions, 90.7% are wooden poles, with the remaining being manufactured in concrete. The inspection of concrete poles is not the objective of this study, and all subsequent discussion is made about wooden poles.

In Table III, a summary of the obtained results for each 23 cities in the five regions studied is presented. The first important observation is the significant number of poles (58%) without identification tag (ID tag). The pole metal tag was probably lost during transport or pole installation, or during in service pole life by weathering or vandalism. It is difficult to know the real causes due to the great variability in tag loss among inspected cities (from 36% in Estancia Velha up to 81% in Rio Pardo). However, it was verified that poles located in urban areas, which corresponds to 87% of inspected poles, are more susceptible to tag loss (59%) than the ones installed in rural areas (54%), suggesting vandalism (more usual in urban areas) as one of the most probable causes. It is important to say that essential pole information, such as brand date, length, wood species and treatment, is lost with the tag. Thus, in this study such crucial information is only available for 4 075 of the inspected poles (42%).

A. Pole Decay Classification

In Table III is also presented the pole decay classification following four classes previously defined (Table II). The results indicated that the majority of the inspected poles present good conservation state (Class 1, 48%) or an initial and treatable decay (Class 2, 24%). On the other hand, 15% of the pole was rejected (Class 3) while 13% was considered in danger (Class 4) and must be replaced. The level of in danger poles is high compare to literature data [17], [18]. For instance, Daugherty [17] reported values ranging 7.6–17.0% and 0.4–2.7% for rejected and in danger poles, respectively, in a study performed in the Southeast USA. However, wood species and treatment are different in the USA and a direct comparison to our results must be taken with caution.

Another aspect to be highlighted is the better pole conservation in rural areas (63% poles on class 1) when compared to urban areas (51% class 1). In addition, the North Frontier region presents three times less in danger poles (Class 4) in rural (6%) than in urban (17%) areas. These results are probably due to the recent expansion of the rural network in Brazil motivated by federal government support.

Important differences among regions were also observed, with Central and South Frontier areas presenting higher (63%) and lower (42%) levels of class 1 poles, respectively. Significant differences on pole classification were also observed among cities. While Santa Maria city presents great quantities of serviceable poles (85% of classes 1 and 2), in Portão these poles represent only 59% of the city inspected network.

However, it was not possible to relate pole decay with environment conditions (soil, climate, etc.. . .) as observed in other studies [8]–[19]. Regions with similar climate and soil such as the North and South Frontiers presented opposite results (Table III).

B. Preservative Type

In the inspected poles containing information tag (ID tag), it was possible ubiquitously to know the wood treatment used. Only poles treated with CCA or creosote were identified. Although Pentachlorophenol was used in Brazil until 1970, the number of in service poles with this preservative should not be significant. On the other hand, the presence of creosote was expected because its banishment is more recent (1995) [13].

For some poles without an ID tag, it was possible to asses the preservative type by the visual inspection (CCA green color; creosote black color). However, this kind of identification must be taken with caution because weathering could change pole color and difficult preservative visual identification.

In Fig. 3, the distribution of the poles preserved with CCA or creosote is shown, in the five regions studied. The greater occurrence of poles preserved with CCA was verified in the North Frontier (93%) while higher percentage of creosote treated poles was verified in the Valleys region (49%). These differences are significant compared to the global mean values (CCA 69%; Creosote 31%) and seem to be related to the differences on both the replacement rates and the pole distribution over rural and urban areas in each region.

C. Pole Lifetime

In Fig. 4 the aging profiles of the inspected poles classed by studied regions is shown. The in service time were divided into four ranges: less than 5 years, from 6 to 10 years, from 11 to 15 years, and more than 15 years. This range division was devised to simplify the data analysis and to take into account the Brazilian Standard [11], which establishes 15 years as the minimum in service treated pole lifetime.

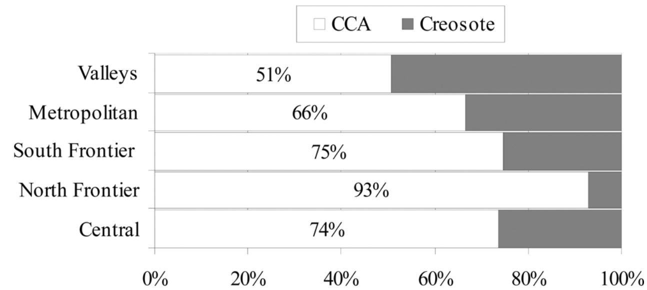

Fig. 3. Type of preservative used (CCA or Creosote) on the poles with identification tag.

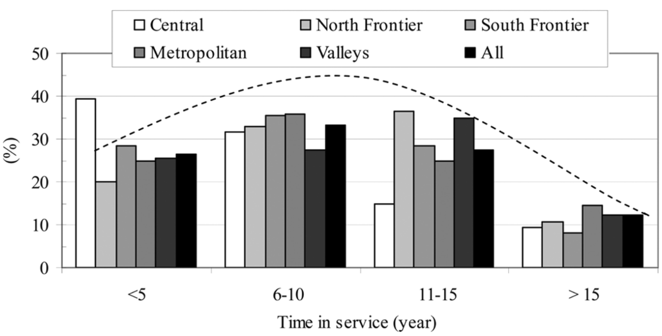

Fig. 4. Variation of the in service time for poles, identified by ID tag, in the different regions studied. Trace line was made only for a better visualization.

It could be observed that the majority of poles (60%) has an in service time of less than 10 years. While the Central region presents the highest level (75%) of young poles (<5 years), the Metropolitan and North Frontier regions have the oldest pole networks (mean age 11–15 years). This difference is probably associated to a more intense replacement rate and the implantation of new networks, especially in rural areas, in specific regions (Central, for instance) in the last decade.

The pole aging profiles observed in this study are very different from other countries. In Europe and North America, the average pole age generally is in the range of 25–50 years [19]–[23] but, as previously mentioned, the species and treatment used are very different as compared to the ones in Brazil. In Australia, where poles are made mostly of Eucalyptus timber treated with CCA, Francis and Norton [18] reported the shorter durability for these structures in the range of 35–45 years, 3–4 times greater than the pole mean ages inspected in this study.

It is important to point out that the durability of the in service wooden pole is related to several factors, mainly: the quality of new wood poles going into service (inherent characteristics of the wood, limited control on white wood and treatment process) [17]; the environmental factors (climate conditions, soil characteristics, nature of fungal/insect attack) [2]–[19]; and the effectiveness of the inspection and maintenance programs [8]–[23]. All these factors are very different in Brazil as compared to other countries, and the use of fast growing eucalyptus species is probably one of the most important aspects for the shorter in service lifetime observed.

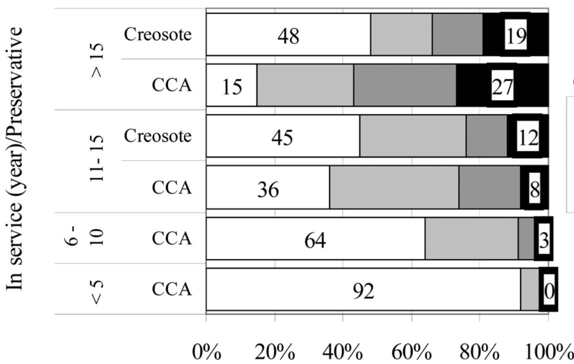

Fig. 5. Influence of the preservative type (CCA or Creosote) on pole decay classification at different in service lifetime ranges.

The influence of preservative type on pole decay classification at different in service lifetime are presented in Fig. 5. A sharp decrease, from 92% to 64%, of sound CCA treated poles (class 1) was verified in the first (<5 years) to the second (6–10 years) age ranges. A less intense diminution on class 1 was observed for 11–15 years (36%) and >15 years (15%) poles. On the other hand, in danger poles increased quickly with pole aging, corresponding to 20% of the CCA-treated poles. These results indicated a fast and significant life decrease of poles probably due to the quality of white wood and the CCA treatment process.

Poles treated with creosote (all >10 years in service) showed better conservation as compared to the poles preserved with CCA in the same aging range. For the oldest range (>15 years), creosote-treated poles presented higher percentage of serviceable poles (Classes 1 and 2), and smaller number of in danger poles (19%) compared to CCA poles in the same classes (Fig. 5).

These results suggest a better action of creosote against fungi decay in Brazilian conditions, probably due to its higher toxicity and a more efficient treatment process compared to CCA.

D. Mycological Study

In all analyzed samples the fungi genera *Paecylomices* and *Penicilium* were present. These fungi genera were also the most abundant among cultures performed in this study. Other genera were also observed in some samples collected in specific areas such as *Aspergilus*; *Trichoderma*; *Botrytis* and *Phyalophora* observed in the North and South Frontier regions.

The genus *Paeyilomyces* (Fig. 6) was the most relevant in this study, since some species of this genus have the ability to degrade toxic substances, called xenobiotic [5], [6]. This fungus could destroy chemicals (such as CCA) toxic to other fungi, and leaving the way open for the xylophages species to act and start the succession of organisms (bacteria and fungi), which culminates in the total wood degradation [6].

IV. Conclusion

The loss of the identification tags interfered negatively in the data analysis, reducing the pole information to only 42% of the inspected poles. The majority of the inspected poles presented good conservation state (48%) or an initial and treatable decay (24%). Fifteen percent of the poles were rejected while 13% were considered in danger and must be replaced, a number significantly higher than that observed in other countries.

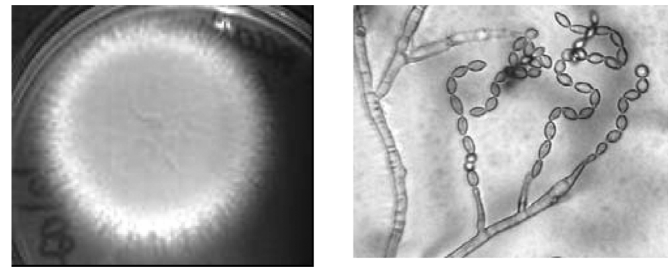

Fig. 6. Images of the *paecilomyces sp*. obtained from incubation culture of the wood pole (right detail magnitude of 400×).

It was not possible to relate pole decay to environment conditions because a great variability on pole conservation was observed among the regions and cities studied. This behavior could be related mainly to the type of preservative used (CCA 69%; Creosote 31%), and also the replacement rates and the pole distribution between rural and urban areas in each region.

Sixty percent of the identified poles (by ID tag) were in service time <10 years, and only 5% presented lifetime longer than the recommended by the Brazilian Standard (>15 years). A better action of creosote against fungi decay in Brazilian conditions was observed, probably due to its higher toxicity. The mycological study showed *Paecilomyces* and *Penicilium* are the most abundant and present genera in all analyzed samples without significant difference among studied regions.

Despite the fact that the results are preliminary, it is possible to use them to estimate a more realistic replacement pole rate. In addition, a careful control of the white wood quality and preservative impregnation and an implementation of a periodical and systematic inspection program in all wooden pole networks are recommended.

Acknowledgment

The authors thank AES Sul for funding and Preschem Pty for the preservative donation. They also thank Dr. R. Guerrero and J. Hellier for their support on the mycological studies and on the field tests, respectively.

References

[1] B. Gustavsen *et al.*, "Simulation of wood-pole replacement rate: Application to distribution overhead lines," *IEEE Trans. Power Del.*, vol. 17, no. 4, pp. 1050–1056, Oct. 2002.
[2] S. V. Datla and M. D. Pandey, "Estimation of life expectancy of wood poles in electrical distribution networks," *Struct. Safety*, vol. 28, pp. 304–319, Oct. 2005.
[3] A. H. Stewart and J. R. Goodman, "Life cycle economics of wood pole utility structures," *IEEE Trans. Power Del.*, vol. 5, no. 2, pp. 1040–1046, Apr. 1990.
[4] E. S. Lepage *et al., Manual of the Wood Preservation*. São Paulo, Brazil: Technological Research Institute, 1986, vol. vol. I/II, Wood Division, (in Portuguese).
[5] R. Guerrero *et al.*, "Morphological cladistic analysis of tropical hymenochaetales (Basidiomycota)," *Mycotaxon*, vol. 79, pp. 467–479, 2001.
[6] C. J. Alexopoulos, *Introductory Mycology*, 4th ed. New York: Wiley, 1996.
[7] *Wood Handbook—Wood as an Engineering Material*. Madison, WI: U.S. Dept. Agriculture, Forest Service, Forest Products Lab., 1999, p. 463.

[8] J. J. Morrell, Wood Pole Maintenance Manual, Research Forest Research Lab., Oregon State Univ.. Corvallis, 1996, p. 47, Contribution 15.

[9] M. A. Horwood and W. D. Gardner, A Service Trial of the Effect of Mechanical and Chemical Variations to the Bioguard Bandage on Efficacy and Environmental Performance Australia, 2002, State Forests of New South Wales.

[10] E. S. Gastaud, Technical and Economical Evaluation About the Pole Use in AES Sul AES Sul, Porto Alegre, 2001, Res. Rep. (in Portuguese).

[11] *ABNT Eucalyptus Preserved Poles for Electrical Distribution Networks*, Standard NBR-8456, 1984, Brazilian Standard Association, Rio de Janeiro, Brazil (in Portuguese).

[12] R. A. C. Altafim *et al.*, “Study of timber cross arms coated with castor oil-based polyurethane resins: Electrical and mechanical tests,” in *Proc. 2004 IEEE Int. Symp. Electrical Insulation*, pp. 556–559.

[13] F. L. R. Vidor, “Inspection and Retreatment Procedures for in Service Wooden Poles Used in Electrical Networks,” M.S. Thesis, Dept. Eng. Materials, Pontifical Catholic University of Rio Grande do Sul, Porto Alegre, Brazil, 2006.

[14] Corrective and Preventive Inspection and Maintenance for Wooden Poles Companhia Paulista de Força e Luz, São Paulo, Brazil, 2001, CPFL, Tech. Paper (in Portuguese).

[15] *OSHA Methods of Inspecting and Testing Wood Poles*, U. S. Dept. Labor, Occupational Safety & Health Administration Standard 1910. 269, 2003, App. D.

[16] *AWPA Book of Standards*. Granbury, TX: American Wood-Preservers’ Association, 2008.

[17] G. L. Daugherty, “The realistic expectation of an in-place wood pole inspection program,” *Wood Design Focus*, vol. 9, no. 2, 1998.

[18] L. Francis and J. Norton, Australian Timber Pole Resources for Energy Networks, A Review. Queensland, Australia, Dept. Primary Industries and Fisheries, 2006.

[19] A. Rahman and G. Chattopdhyay, “Soil factors behind in ground decay of timber poles: Testing and interpretation of results,” *IEEE Trans. Power Del.*, vol. 22, no. 3, pp. 1897–1903, Jul. 2007.

[20] M. Mankowski, E. Hansen, and J. Morrell, “Wood pole purchasing, inspection, and maintenance: A survey of utility practices,” *Forest Products J.*, vol. 52, no. 11/12, pp. 43–50, 2002.

[21] H. Li, G. S. Bhuyan, and D. Tarampi, “Life prediction of aging wood poles and subsequent inspection practice—A case study,” *Int. J. Comput. Mathemat. Elect. Electron. Eng.*, vol. 23, no. 1, pp. 15–20, 2004.

[22] J. D. Bouford, J. M. Teixeira, and C. A. Warren, “The natural replacement process versus the aging infrastructure of distribution poles,” *IEEE Trans. Power Del.*, vol. 23, no. 3, pp. 1522–1526, Jul. 2008.

[23] B. Gustavsen *et al.*, “Assent management of wood pole utility structures,” *Electr. Power and Energy Syst.*, vol. 27, pp. 641–646, 2005.

Flavio L. R. Vidor was born in Brazil in 1962. He received the B.S. degree in biology from the University of Vale do Sinos, Brazil, in 1996 and the M.S. degree in materials engineering in 2006 from the Pontifical Catholic University of Rio Grande do Sul (PGETEMA/PUCRS), Porto Alegre, Brazil, where he is currently pursuing the Ph.D. degree.

His research areas include inspection programs and mycological pole decay.

Marçal Pires received the B.Eng. degree from the Federal University of Rio Grande do Sul (UFRGS), Brazil, in 1988 and the Ph.D. degree in environmental chemistry from Federal University of Lausanne, Lausanne, Switzerland, in 1995.

Currently, he is a Professor of the Program of Engineering Materials of the Pontifical Catholic University of Rio Grande do Sul (PGETEMA/PUCRS), Porto Alegre, Brazil. He is active in research projects about wood pole inspection, retreatment, and timber waste analysis and disposal.

Berenice A. Dedavid received the B.S. degree in physics in 1988 and the Ph.D. degree in materials science in 1995, both from the Universidade Federal do Rio Grande do Sul, Brazil.

Currently, she is a Professor at the Pontifical Catholic University of Rio Grande do Sul (PGETEMA/PUCRS), Porto Alegre, Brazil, where she is active in research projects about wood mechanical proprieties.

Pedro D. B. Montani was born in Porto Alegre, Brazil, in 1968. He received the B.Eng. degree in electrical engineering from

Currently he is working with Management of the Research Program of the AES Sul since 2006.

Adriano Gabiatti was born in Porto Alegre, Brazil, in 1978. He received the B.Eng. degree in mechatronics and the M.S. degree in energy systems from the Pontifical Catholic University of Rio Grande do Sul (PGETEMA/PUCRS), Porto Alegre, Brazil.

Currently, he is working with the Management of the Maintenance Program for Distribution Lines on AES Sul Distribuidora Gaúcha de Energia S/A, Brazil.