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A COMPARATIVE WAVELET ANALYSIS OF POWER QUALITY INDEXES AND LIGHTNING ACTIVITY

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1. INTRODUCTION

Lightning is a significant cause of transients, interruptions and damages in electric power systems. The situation is more critical for transmission and distribution systems in regions where its occurrence is significant. Some estimates indicate that the economic losses caused by lightning to electric power systems reach approximately 20 billion dollars in United States and one billion dollars in Brazil (Pinto, 2011).

In order to minimize these losses several lightning monitoring technologies have been developed and used for at least 30 years in many countries to support electric power applications. The main technology is the Lightning Location Systems – LLS (Cummins et al., 2000). They have been used in conjunction with specific computational tools by more than 200 power utilities for many different applications dedicated to reduce the lightning impact on electric power systems.

Although most applications of LLS have benefited power utilities by providing in real time location of power failures and lightning warnings to accelerate the recovery of the system, historical information is very important to analyze the cause of permanent fault events or the performance of different parts of the system, quantifying the effectiveness of different lightning protection methods.

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The goal of this study is to investigate the dependence of the average duration of power service interruptions (DEC) and the average frequency of power service interruptions (FEC) monthly indexes on the lightning monthly activity in the region of operation of the EDP companies in the states of São Paulo and Espirito Santo, Southeast Brazil, for the period from 1999 to 2011 using the cross-wavelet analyses.

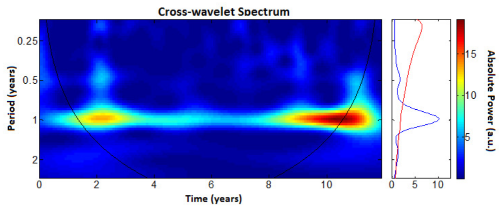
2. DATA

In this study, data obtained by the RINDAT (Integrated Lightning Detection Network) from 1999 to 2011 in the region of operation of the EDP Bandeirante Energia and EDP Escelsa companies in the states of São Paulo and Espirito Santo, Southeast Brazil were used. This network is a hybrid network consisted of LPATS and IMPACT sensors. More details about RINDAT can be found in Pinto Jr. et al. (2006). The region is covered by RINDAT with detection efficiency around 85% for flashes (Naccarato, 2009).

The cross-wavelet analysis was used to study the frequency content of the power quality monthly indexes and monthly lightning activity. The cross-wavelet spectra were generated using Matlab functions developed by several research groups (Torrence and Compo, 1998; Grinsted et. al, 2004; Neto et al., 2010).

3. DISCUSSION

The normalized wavelet spectra of monthly lightning activity, DEC and FEC for both companies are showed in Figures 1 to 3, respectively. The spectra in Figures 2 and 3 are filtered around one year to emphasize the results discussed afterwards.



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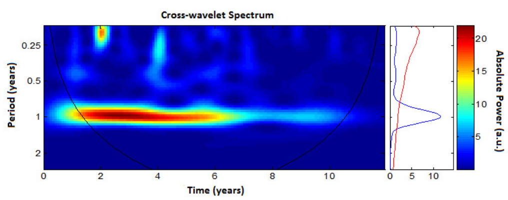

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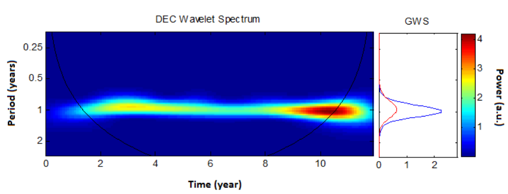
Figure 1. Normalized wavelet spectra of monthly lightning activity for the region of the: (a) EDP Bandeirante; (b) EDP Escelsa.



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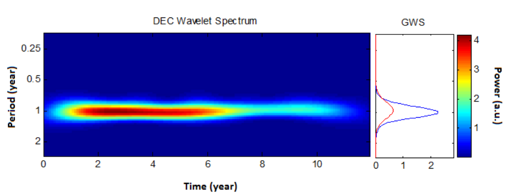

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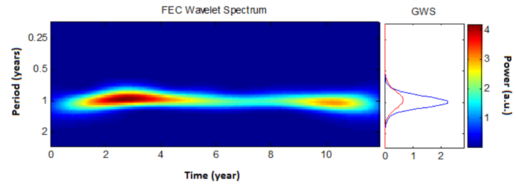
Figure 2. Normalized wavelet spectra of monthly DEC index of the: (a) EDP Bandeirante; (b) EDP Escelsa.



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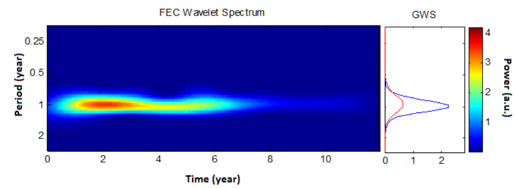


(b)

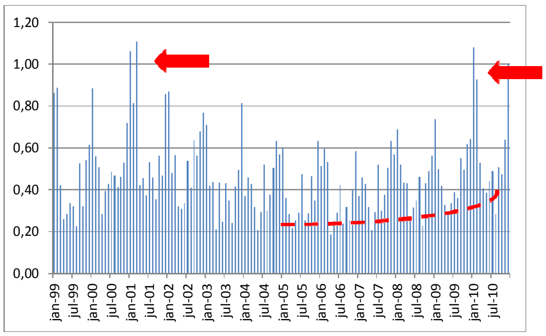
Figure 3. Normalized wavelet spectra of monthly FEC index of the: (a) EDP Bandeirante; (b) EDP Escelsa.

Figure 1 shows that for both companies the cross-wavelet spectrum of the lightning activity has significant power variability for the period of one year associated with a well-established seasonal behavior of lightning activity. In addition, they show that the power changes with time, showing in the case of EDP Bandeirante Energia two peaks around 2001 and 2010, while in the case of EDP Escelsa only one peak extending from 2001 to 2004.

Figures 2 and 3 show that the cross-wavelet spectrum of DEC and FEC follow in general the correspondent spectra of lightning activity, with a clear periodicity in one year. However, a closer look in these figures indicates that the spectrum of FEC for the EDP Bandeirante Energia showed in Figure 2 has the power in the second peak lower than the first in contrast with the behavior in Figure 1 for the power related to the lightning activity.

In order to understand the different behavior of FEC and lightning activity in EDP Bandeirante, it is showed in Figure 4 a histogram of the monthly values of the FEC index for the EDP Bandeirante Energia and EDP Escelsa. The figure shows that, differently of the EDP Escelsa case, in the

EDP Bandeirante the index has been increasing in the winter in the last years, a feature that it is caused by other agent than lightning, since at this time of the year no lightning are observed in the area of the EDP Bandeirante.



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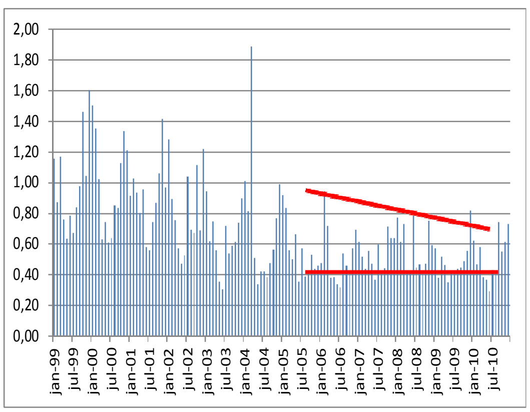

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Figure 4. Monthly values of the FEC index of the: (a) EDP Bandeirante; (b) EDP Escelsa.

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4. CONCLUSION

The variability in the cross-wavelet spectra of the monthly values of the DEC and FEC power quality indexes and monthly values of lightning activity are compared and the comparison suggests interesting features that can potentially be used by power companies to improve power quality and predict future trends in these indexes.

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