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OPERATIONAL PERFORMANCE INDEXES FOR THE APPLICATION OF THE ENERGIZED SHIELD WIRE LINE TECHNOLOGY

José Ezequiel Ramos
Fundação Universidade Federal de Rondônia (UNIR) – Porto Velho – Rondônia
http://buscatextual.cnpq.br/buscatextual/busca.do;jsessionid=77FAFE2A97F50BB0EBB3E3B129B8152E.jb_buscacv_218-1

Alexandre Piantini
Universidade de São Paulo
Instituto de Energia e Ambiente (IEE/USP)
São Paulo – São Paulo
http://buscatextual.cnpq.br/buscatextual/busca.do;jsessionid=7 7FAFE2A97F50BB0EBB3E3B129B8152E.jb_buscacv_218-1

Ary D'Ajuz
Universidade Federal de Itajubá (UNIFEI)
Brasília – Distrito Federal
http://buscatextual.cnpq.br/buscatextual/visualizacv.do?id=K4337987P3

Valdemir Aparecido Pires
Energisa Rondônia
Porto Velho – Rondônia
http://buscatextual.cnpq.br/buscatextual/visualizacv.do?id=K4751190Y7

Paulo Roberto de Oliveira Borges
Fundação Universidade Federal de Rondônia (UNIR)
Porto Velho - Rondônia
http://buscatextual.cnpq.br/buscatextual/visualizacv.do?id=K4751612H2

Abstract: This article presents the results of the research on the operational performance of the energized shield wire line (SWL) implemented in Rondônia, in the localities of Jaru and Itapuã do Oeste, in order to obtain a set of indices, here called operational reference indices. To obtain these indices, records of more than 180 months of operation of the SWL Rondônia were analyzed. In addition, the incidences of lightning in the region were analyzed, as well as the rainfall rates, and a high correlation was found between these events and the interruptions caused by lightning.
Keywords: SWL technology, interruptions, operational indices, atmospheric discharges.

INTRODUCTION

Despite the technical and economic feasibility of the SWL technology, demonstrated by Iliceto et al. (2000), Ramos et al. (2009, 2011, 2014), how can such technology be included in the set of other alternatives if it is not sufficiently known? This is the great challenge faced by new technologies, as stated by Souza et al. (2004) in their assessment of barriers and facilitators for the production and diffusion of renewable technologies in the Amazon region. The lack of knowledge of existing technologies in the national and international market, as well as the results of experiences applied in the region, leads to the rejection of technology in certain situations and the rework of research in others.

In order to face this challenge, a detailed analysis of the interruptions verified throughout the entire period of operation of the SWL Jaru (from 1996 to 11/14/2000) and the SWL Itapuã, since its entry into operation was adopted as one of the alternatives, which took place on 09/22/1997, until December 31, 2007. The reference indices resulting from this analysis are: equivalent duration of interruption by consumer of the considered set, expressed in hours (EDC) and equivalent frequency of interruption per consumer of the considered set (EFC). From these indices are also obtained: mean time of re-establishment, given in hours/interruption/year (T); failure rate (F) and reliability per consumer (C).

It must be clarified that the electrical systems of the localities of Jaru and Itapuã do Oeste, where the SWL technology was implemented, are here called SWL Jaru and SWL Itapuã. The expressions Sistema SWL are also adopted to designate any of the facilities or specifically the SWL technology in Rondônia.

MATERIAL AND METHODS

The object of study is the SWL technology in the three-phase scheme (Iliceto et al., 1989). This technology is based on the use of lightning protection cables from an alternating current transmission line (LTCA), so that, without compromising the basic function of protecting the line conductors against atmospheric discharges, the lightning protection cables can be also used to transport electrical energy, making it possible to combine, in the same infrastructure, a High or Extra High Voltage system with a Medium Voltage system. Figure 1 presents the main features of the SWL technology and in Figures 2, 3 and 4, the photos of the installations, showing the supplying and distributing substations and the tower with insulated lightning cable.

The material used to analyze the interruptions was obtained from the following documents: a) SWL facilities operation book; b) outages reports; d) daily information produced by the Systems Operation Center (COS); e) occurrence book with records made by the coordination of the locality of Itapuã do Oeste; f) days of thunderstorms recorded by the Porto Velho

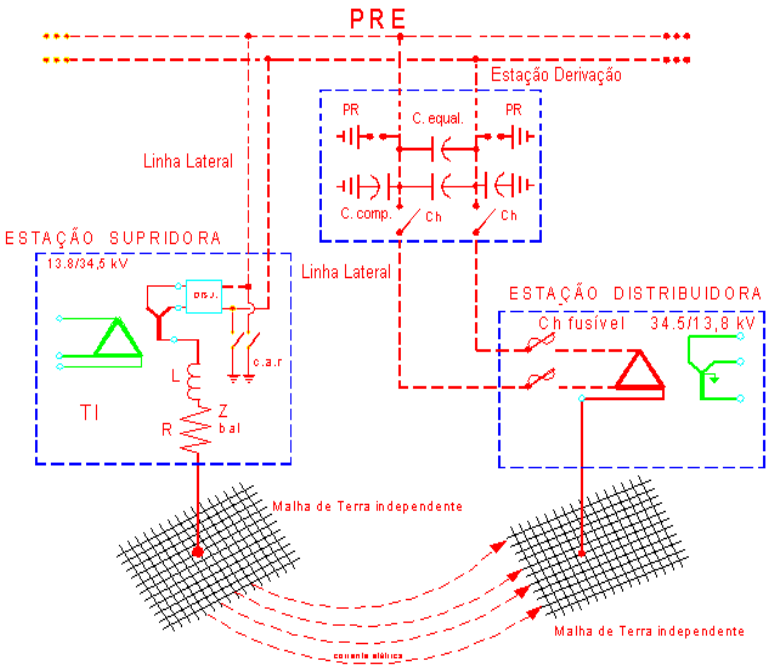

Figure 1. Illustrative diagram of the PRE technology in the three-phase scheme.

Figure 2. Substation supplying the PRE Itapuá

Figure 3. Detail of the lightning rod insulation at the top of the tower

Figure 4. Distribution Substation of PRE Itapuã

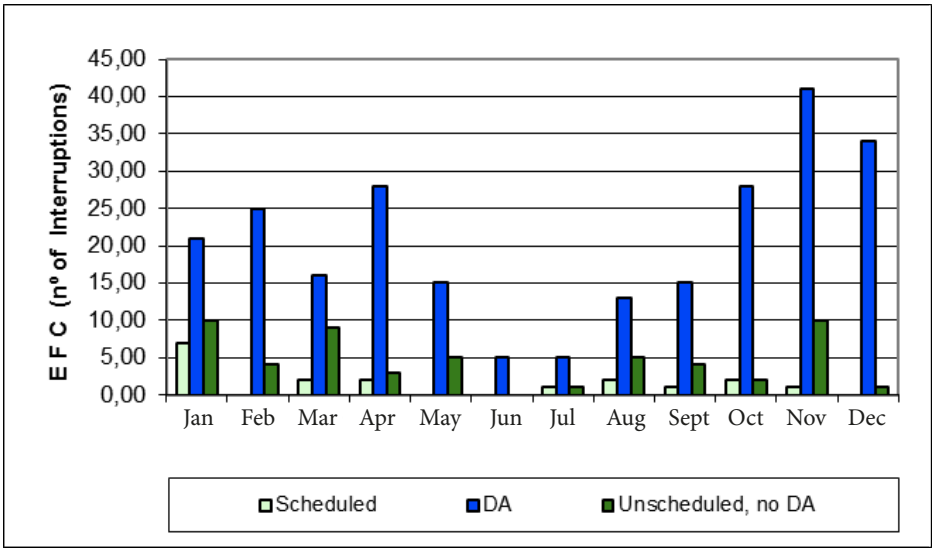

Figure 5. Characteristic behavior of the EFC associated with the PRE Jaru, in the period from 1996 to 11/14/2000

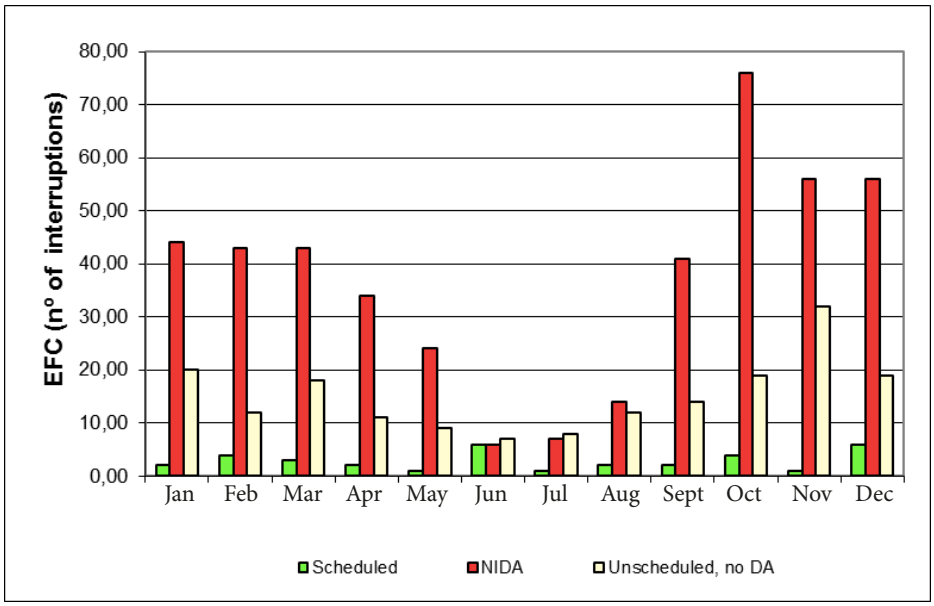

Figure 6. Characteristic behavior of the EFC associated with the PRE Itapuã, in the period from 09/22/1997 to 2007

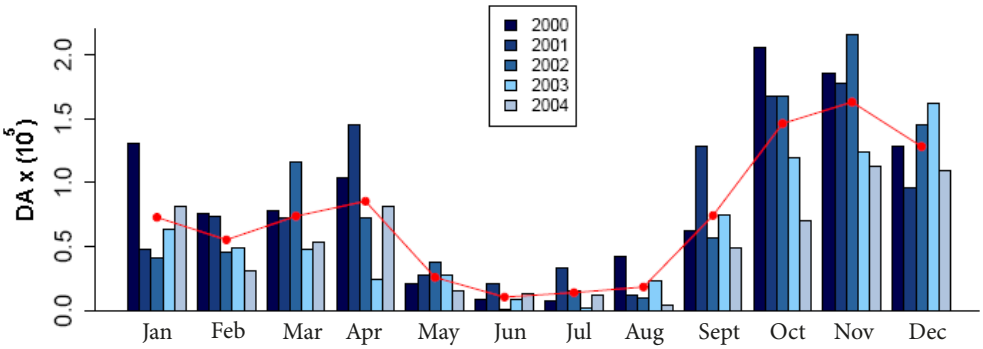

Figure 7. Monthly distribution of the number of lightning strikes in the State of Rondônia, measured by the BLDN network.

Source: adapted from Albrecht (2008).

Meteorological Station.

Regarding the method, the interruptions were classified according to the recommendations contained in ELETROBRAS/CODI (1982), that is, the interruptions were classified according to origin and cause. The methodology used to calculate the continuity indices was based on Resolution 024 of the National Electric Energy Agency (ANEEL, 2000).

In order to obtain the representative indexes of the operational performance of the SWL system, initially the data of the interruptions that refer only to the operational performance of the SWL Jaru and SWL Itapuã were summed and totalized in relation to each month, thus obtaining an average value for each month. At the end, the monthly average values of EDC and EFC of each SWL were added and then the arithmetic averages were extracted, resulting in the representative monthly indexes of the SWL Rondônia system.

RESULTS AND DISCUSSION

During the 4,875 years of operation of the SWL Jaru, EDC = 143.65 hours and EFC = 318 interruptions were recorded, these results being of internal origin, that is, they only concern the SWL technology. Likewise, in the 10.28 years of operation of the SWL Itapuã, EDC = 443.45 hours and EFC = 659 interruptions were recorded.

Figures 5 and 6 clearly show that the behavior of the SWL System is basically determined by the lightning event, indicated in the graph as the number of interruptions by atmospheric discharges (NIDA). In order to confirm this seasonally characteristic behavior, lightning data recorded by the "Brazil Lightning Detection Network" (BLDN) in the period from 2000 to 2004 were used in the scope of this research, whose profile is shown in Figure 7.

Comparing the graph in Fig. 7 with those shown in Figures 5 and 6, there is a clear similarity with the behavior of interruptions caused by lightning. This demonstrates, above all, that the criteria for classifying atmospheric discharges were correct. The rainfall data in the region were also statistically correlated with the records of interruptions by atmospheric discharges, and a high correlation was found between them.

Since the SWL systems of Jaru and Itapuã have similar behaviors, their indexes were added and, from the result, the arithmetic mean was extracted, thus resulting in the set of representative indexes of the SWL system, as shown below:

- EDC = 36,16 hours/year; EFC = 64.94 interruptions/year;
- T = 0,56 hour/interruption/year; F = 0.82 failure/km/year;
- $F_{(NIDA)}$ = 0,60 failure/km/year; C = 0,9959.

CONCLUSIONS

The methodology used to classify the interruptions, especially in relation to their causes, proved to be correct, since the resulting data format a fault profile that dialogues with the lightning data measured by the BLDN, in addition to presenting a high correlation with the rainfall in the region. Therefore, if the behavior of the SWL technology is basically determined by the interruptions caused by atmospheric discharges, the operational indices obtained here are reliable. Thus, these results allow us to affirm that the representative indices of the entire SWL system can be considered as reference indices for the application of the SWL technology in regions whose lightning density is similar to that of Rondônia and whose transmission line tower geometry are similar to that of the LT 230 kV in the section between UHE Samuel and Ji-Paraná.

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