Available online at www.sciencedirect.com
SCIENCE DIRECT®
ELSEVIER
Electric Power Systems Research 76 (2006) 616–625
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

# Transient conditions in CCVTs outputs and their effects on the detection of traveling waves

Francisco Salgado Carvalho [a,*], Sandoval Carneiro Jr. [b]

[a] Department of Electrical Engineering, Fluminense Federal University (UFF), Rua Marquesa de Santos 42/1403, Laranjeiras, Rio de Janeiro 22221-080, RJ, Brazil
[b] Electrical Engineering Program (COPPE) and Electrical Engineering Department, Federal University of Rio de Janeiro, Rio de Janeiro, RJ, Brazil

Available online 25 January 2006

**Abstract**

It can be considered that coupling capacitor voltage transformers have two outputs. The first is the fundamental frequency output, normally used to feed relays and meters. This output has a limited bandwidth and its response is typical of a low-pass filter. The second is the high-frequency output, normally used for Power Line Carrier application. This paper demonstrates, by means of digital simulations conducted with EMTP/ATP, that it is possible to capture, using the second output, the appropriate traveling wave voltage signals that are required for the correct operation of an EHV transmission line fault locator system, for line maintenance purposes. This paper also demonstrates that, due to the behaviour of the high-frequency output, it is possible to obtain the voltage information that is needed to locate lightning discharges that reach the line and do not cause insulator flashover. This information can be very important for transmission line maintenance purposes.


*Keywords:* Coupling capacitor voltage transformer; Digital simulation; EHV transmission lines; EMTP/ATP; Frequency response; Traveling waves

## 1. Introduction

The correct location of faults on EHV power transmission lines is important to allow quick maintenance action of the repair crews. The Brazilian system is characterized by hydroelectric power plants connected to the consumer centres by long transmission lines. Its future growth is being planned to occur mainly towards the north of the country, and this will require new long transmission lines.

Nowadays, studies and investigations of the EHV power system on the Brazilian north region, where transmission lines routes go through dense forests and rugged regions, indicate the need to look for more precise fault location methods, in comparison with the power frequency phasor schemes. The fundamental frequency based methods are usually available from algorithms integrated with the software of digital protection systems (numeric relays) and/or digital fault recorders (DFRs). Fig. 1 shows an illustration of the Brazilian North–South 500 kV Interconnection, between Brasilia and Imperatriz substations [1]. One interesting aspect is that the new lines in the Brazilian EHV system in the north region are equipped with Optical Ground Wires (OPGW) for communication and protection purposes, instead of Power Line Carrier (PLC) in their project.

The studies presented in this paper are part of a broader work aiming at the study of a traveling wave fault location method based on voltage information. That is, a method, that can be proposed for the new Brazilian EHV transmission lines, and does not present the same limitations as the fundamental frequency based methods [2].

In the development and utilization of high-speed protective relays or, as it is the interest in this study, of a traveling wave fault locator system for transmission line maintenance purposes, the transient response of coupling capacitor voltage transformer (CCVT), from which the voltage information is drawn, should be considered. This is particularly important if the relays or the fault locator system work on the high-frequency fault generated transients, rather than 60 Hz quantities.

Many researchers have developed sophisticated traveling wave based fault locator algorithms based on voltage information [2–5]. In order to fully exploit the advantages of such

* Corresponding author at. Electric Power Research Center – CEPEL, Rio de Janeiro, RJ, Brazil. Tel.: +55 21 2556 0982; fax: +55 21 2556 0982.
*E-mail addresses:* fmsalgado@uol.com.br (F.S. Carvalho), sandoval@dee.ufrj.br (S. Carneiro Jr.).

0378-7796/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.epsr.2005.12.008

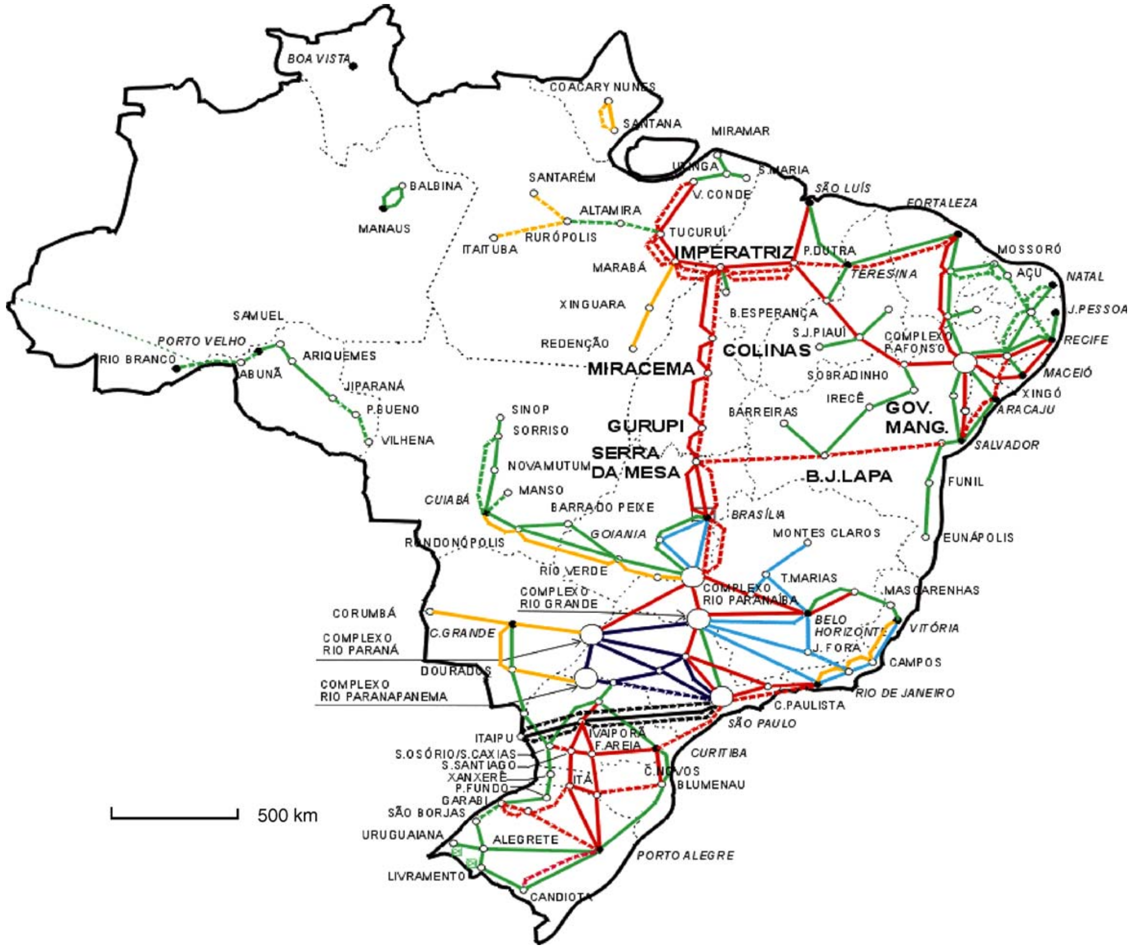


Fig. 1. Geographical location: Brazilian North–South 500 kV Interconnection.

schemes it is necessary to employ voltage transducers of sufficient bandwidth to allow accurate detection of the fast-rising waveforms associated with traveling waves. Although equipment such as optical voltage transducers may be considered available from industry [6], in the Brazilian EHV transmission system all existing voltage instrument transformers are designed with 60 Hz in mind.

In a previous paper [7], the authors have shown that coupling capacitor voltage transformers secondary voltages, normally applied to conventional relays and meters, do not comprise the appropriate information, present in the primary voltages, for a scheme that operates on the high-frequency fault generated transients. In the mentioned paper [7], it can be seen, regarding its secondary voltages, that a CCVT behaves as a low-pass filter.

To overcome this limitation, Zhang et al. [8] proposed a scheme, based on wavelet analysis, in which they employed a specially designed transient voltage detector (TVD), developed by Stalewski and Weller [9], to capture the fault generated transients, instead of conventional CCVTs that have limited bandwidth. This is a non-standard equipment and it is not adopted in the Brazilian substations.

Presently, due to the deregulation of power industry, increased competition between utilities and new regulatory framework of the electric sector, it is difficult to have the transmission system available for field tests, to investigate new technologies that may be applied, specially considering for line fault application.

In this context, the objective of this paper is to demonstrate, by means of digital simulations conducted with the Alternative Transients Program (ATP) [10], GTPPLOT [11] and MATLAB [12], that it is possible to capture the appropriate traveling wave information using a high-frequency output from a CCVT. This output behaves as a high-pass filter that rejects lower frequencies. This paper also has the objective to demonstrate that, due to the transient response of the high-frequency output, it is possible to obtain the high-frequency voltage information necessary to locate lightning discharges that reach the lines and do not cause insulator flashover. This feature is not found in the power frequency based methods and may be useful for transmission line maintenance purposes.

This method was first proposed by Stringfield et al. [13], as cited in [14]. Part of the studies presented in this paper draws primarily from the pioneering work they did at Bonneville Power Administration. More recently, Lee and Mousa [15] described a practical experience in an application for the British Columbia Hydro 500 kV system.