



# Strengths and limitations of a new phasor estimation technique to reduce CCVT impact in distance protection

E. Pajuelo, G. Ramakrishna\*, M.S. Sachdev

Power System Research Group, Department of Electrical and Computer Engineering, University of Saskatchewan, 57 Campus Drive, Saskatoon, SK S7N 5A9, Canada

## ARTICLE INFO

### Article history:

Received 16 July 2008

Accepted 5 October 2009

Available online 3 November 2009

### Keywords:

Coupling capacitor voltage transformer

Distance relays

Phasor estimation

Least squares method

## ABSTRACT

This paper evaluates the performance of a new least squares approach that improves the accuracy and speed of convergence of the voltage phasors estimated during CCVT transient conditions. A justification of the validity of the linear mathematical model for the CCVT used is provided together with a short study about the risk of transient ferroresonance. Also, a discussion is presented about operating times of numerical distance relays and the importance of the new phasor estimation considered. The methodology followed to achieve a realistic evaluation in a variety of scenarios is presented. The results show the improvements achievable in most conditions, but also highlight an example scenario where the new method has limitations.

© 2009 Elsevier B.V. All rights reserved.

## 1. Introduction

The coupling capacitor voltage transformer (CCVT) is typically used to obtain a scaled down replica of high voltage signals from the power system for use by measurement and protection systems. The behavior of a CCVT during fault conditions is not as good as desired, because distortions are introduced in the voltage signals. This behavior is temporary and is known as CCVT transient response. This transient response presents some characteristics that are dependent on the internal CCVT circuit and components. In this work, a new least squares method that uses the knowledge of this internal configuration of the CCVT to overcome the difficulties imposed by this transient behavior is considered.

Distance protection relays use the information from voltage and current signals to identify the presence of a faulted condition in certain area of the power system. The state of the art relays are based on microprocessor architectures, and are known as numerical relays. Numerical distance relays use in most cases information from the fundamental frequency voltage and current to make the protective decision. To obtain this fundamental frequency information typically phasor estimation methods are used.

The CCVT transient behavior in many cases has a negative impact on the accuracy and speed of convergence of typical phasor estimator methods. In other words, the CCVT transient may cause a temporary phasor estimation error. This error affects the numerical distance relays by causing a transient overreach or underreach

condition. In this paper, a new phasor estimation method based on the knowledge of the CCVT [1] is first briefly described and then evaluated.

Also in this paper, the validity of the linear CCVT model used is emphasized, based on other models from the literature. To reinforce this point a short study is included to clarify any concern about the risk of ferroresonance for overvoltage caused by line reclosures. Also, a discussion is presented about operating time on distance relays, the variables involved and the importance of the new phasor estimation method on this subject.

Also in this paper, the methodology followed to evaluate the new phasor estimation method is presented. The purpose of this evaluation is not only to verify the improvements achievable, but also to find any limitations of the new method. The conditions under which the method has limitations are of particular importance and they should be avoided. Results from the evaluation are presented, showing one case of improvement and one case where it has limitations.

## 2. CCVT characteristics

The CCVTs perform three main functions: scale down the power system voltage to the secondary voltage level required by protection, measurement and control equipments in a substation; provide electrical isolation from the high power system voltage; and normalize the secondary voltage to a range typical from 100 to 120 V according to the standards [2] in use.

A CCVT, as shown in Fig. 1, consists of three main elements: capacitive divider, series inductance, and intermediate potential transformer (PT). The capacitive divider scales down the high pri-

\* Corresponding author. Tel.: +1 306 966 5385; fax: +1 306 966 5407.  
E-mail address: [rama.krishna@usask.ca](mailto:rama.krishna@usask.ca) (G. Ramakrishna).