IV INTERNATIONAL WORKSHOP
The Use of Synchrophasors in Power Systems
An Indispensable Infrastructure in the 21st Century

Assessing the Performance of a Thevenin-Based Algorithm to an Actual Voltage Instability Incident Using Real PMU Data

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***Abstract*-- This letter shows an actual voltage instability incident that has occurred in the Northern part of the Brazilian Interconnected Power System (BIPS), and how it was captured by the algorithm proposed by Corsi&Taranto in [1] using real voltage and current synchrophasor measurements.**

***Index Terms*-- Field application, Thevenin-based algorithm, voltage instability, synchrophasor data.**

1. INTRODUCTION

The algorithm proposed by Corsi & Taranto in [1] for real-time identification of voltage instability provided promising results in computer simulation studies. This algorithm based on local synchrophasor data relies on Thevenin and load impedances matching condition to identify the proximity of the long-term voltage instability, driven typically by OLTCs and OELs.

It is well known that the algorithm is not suited for short-term voltage instability induced by large disturbances, such as short-circuit, line outages and generators trips. In these cases, the variations of load and Thevenin impedances are faster compared to the dynamics leading to voltage instability. However, the effectiveness of the algorithm proposed in [1] has not been assessed so far, for any of the known short-, mid- or long-term voltage instability mechanisms. So, it is intended to discuss this important aspect in this letter, using real synchrophasor measurements captured during a voltage instability incident in a HV network.

On August 21, 2013 at 14:47 local time, an incident mixing short-term voltage instability dynamics and mid-term undervoltage generation tripping and load shedding, caused by an unreported event, occurred in the Tramo Oeste area of the Northern part of the Brazilian Interconnected Power System (BIPS), driving consumers with a total load of 163 MW into a blackout. Contrary to well-documented worldwide incidents of short-term voltage instability, which occurred straight after large disturbances, the rapid voltage drop in Tramo Oeste area was not caused by a large disturbance, according to the disturbance analysis report elaborated by ONS (The Brazilian ISO) [2]. The Tramo Oeste system one-line diagram is presented in Fig. 1.

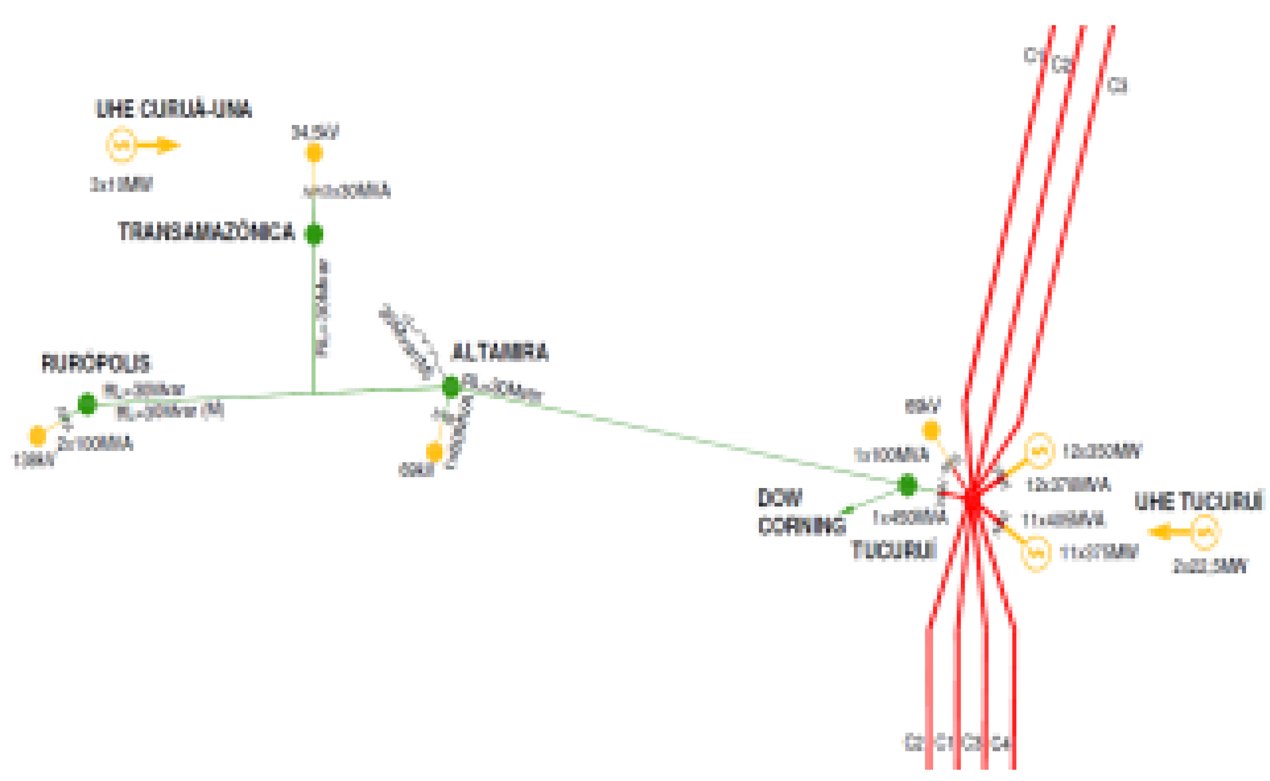

Fig. 1. Tramo Oeste system (red lines – 500 kV and green lines – 230 kV)

2. EXPERIMENTAL RESULTS

The voltage and current phasors were measured at the Ruropolis 230 kV bus with a sampling rate of 10 phasors/s. Fig. 2 shows the SE-Ruropolis 230 kV bus voltage profile during voltage instability incident. The root cause that triggered the voltage drop at 7.7s was not identified neither by the utility nor by the ISO.

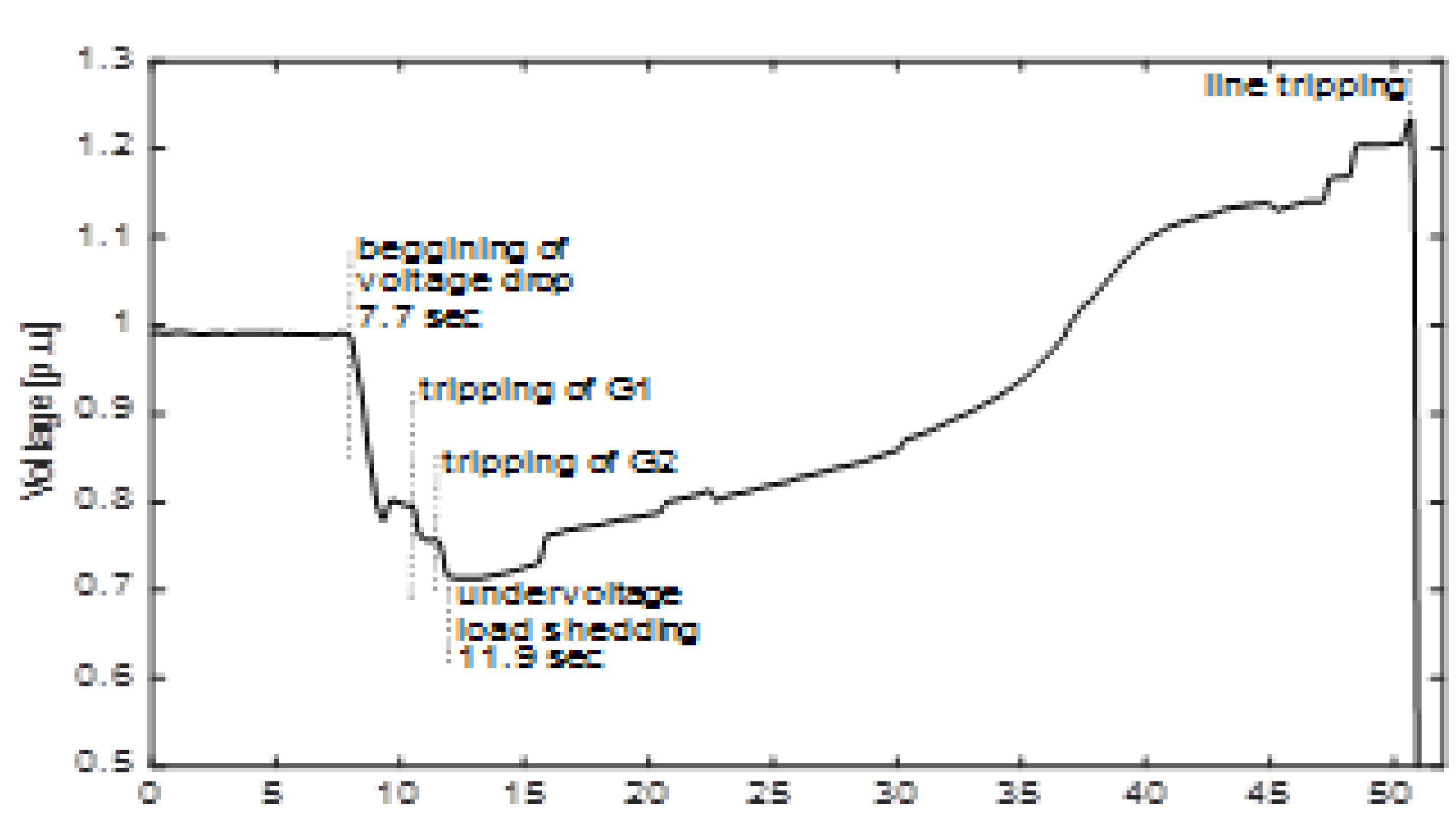

Fig. 2. Voltage at Rurópolis 230 kV bus

Fig. 3 shows the load and Thevenin equivalent impedances. It can be observed, before and during the rapid voltage drop, that the Thevenin impedance has experienced minor variations. This behavior is coherent with the analysis done by the ISO through oscillography and SCADA data, that there was no large disturbance in the Tramo Oeste area upstream the SE-Rurópolis to justify the voltage instability. On the other hand, the load impedance has experience major variations. This indicates that the unreported event probably has occurred downstream SE-Rurópolis.

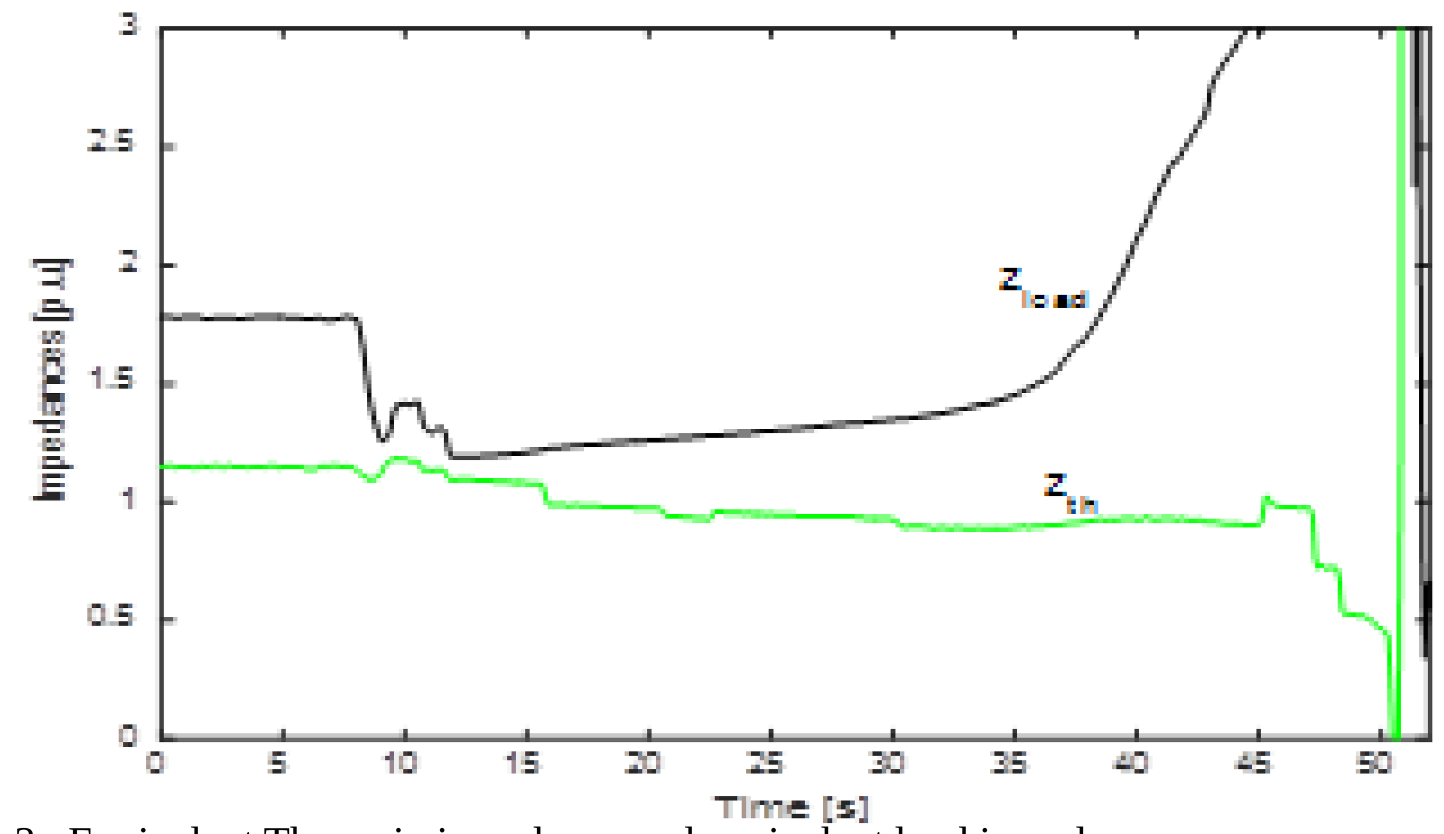

Fig. 3. Equivalent Thevenin impedance and equivalent load impedance

These results highlight *the importance of analyzing the chronological evolution of the voltage instability under the point of view of impedances*. As the impedances calculation captures the voltage instability mechanisms, this approach can assist post-morten analysis, mainly for cases when operators do not have explicit knowledge of protection and control actions. For example, the information about OEL status was not reported by the Tucurui hydro power plant, but even tough, the observation of the Thevenin impedance profile indicates that the OEL was not activated, otherwise, it would be observed a steep increase in the Thevenin equivalent impedance. It can be noted in Fig. 3 a narrow nonzero distance between impedances, right after the rapid voltage drop. This result proves that *the impedance matching condition at the load bus occurs after the voltage drop has begun.* This means that *it is risky to wait impedances crossing to take remedial actions.* As the Thevenin and load impedances curves do not intercept, from a practical point of view it seems *intuitive to use a high-risk threshold voltage instability indicator to trigger remedial actions*.

Fig. 4 shows the voltage instability risk indicator. It is noted that the Thevenin-based algorithm would be able to identify the short-term voltage instability at 9.125 s (9.075 s + 3 cycles). This allows to conclude that the load shedding using the impedance approach would be done 2.775 s before the undervoltage relays of the distribution networks, which operated at 11.9 s, as shown in Fig. 2.

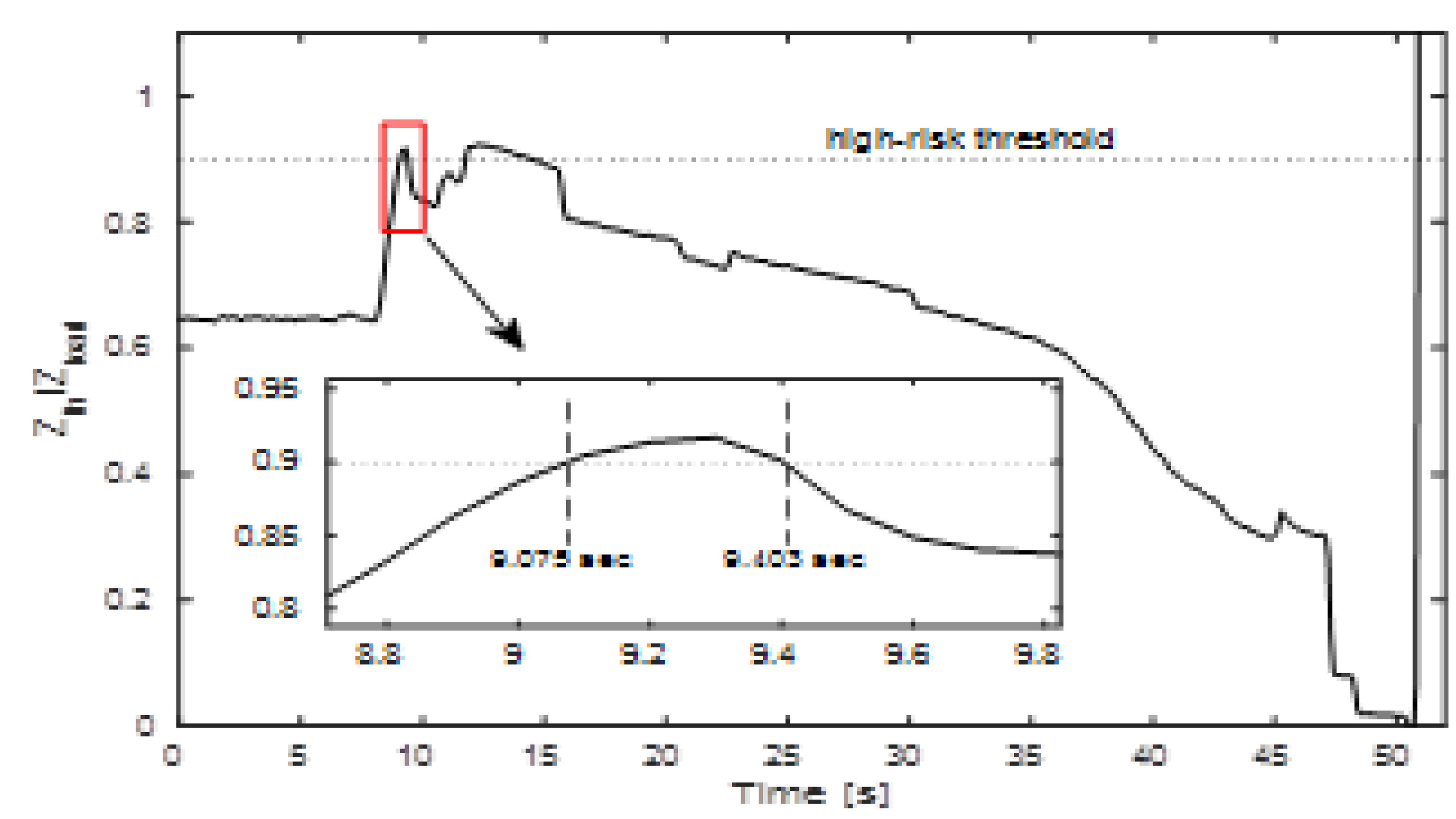

Fig. 4. Voltage instability risk indicator and high-risk threshold

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