International Workshop on
Dynamic Stability Challenges of the Future Power Grids

Efficiency of blocking OLTC automation, and its impact on LTVS

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Agenda

- Introduction
- Methodology
- Results
- Conclusions

Introduction

Why did we look into this?

- OLTCs often act as a major facilitator of voltage collapses by pre-emptively restoring load voltages and thus increasing system stress
  - Nowadays, more and more OLTCs operate automatically
- The two major outages in Sweden (1983 and 2003) have both been due to long-term voltage instability
- Then, there is the Emergency and Restoration network code, article 17:

Article 17

Automatic scheme against voltage collapse

1. The automatic scheme against voltage collapse of the system defence plan may include one or more of the following schemes, depending on the results of a TSO's assessment of system security:

(a) a scheme for low voltage demand disconnection according to Article 19(2) of Regulation (EU) 2016/1388;

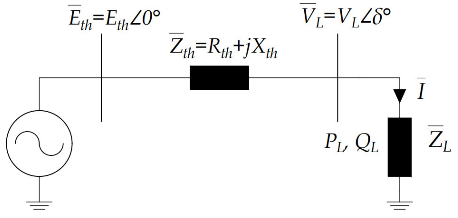
(b) a blocking scheme for on load tap changer according to Article 19(3) of Regulation (EU) 2016/1388; and

(c) system protection schemes for voltage management.

Voltage instability indicators

Aim: as quickly and robustly as possible indicate that the system has become unstable
- **Voltage magnitudes:** Simple, but difficult to interpret, and can sometimes be misleading
- **Local voltage stability indicators:** Only requires local measurements. Most are based on real-time estimation of Thévenin equivalents:

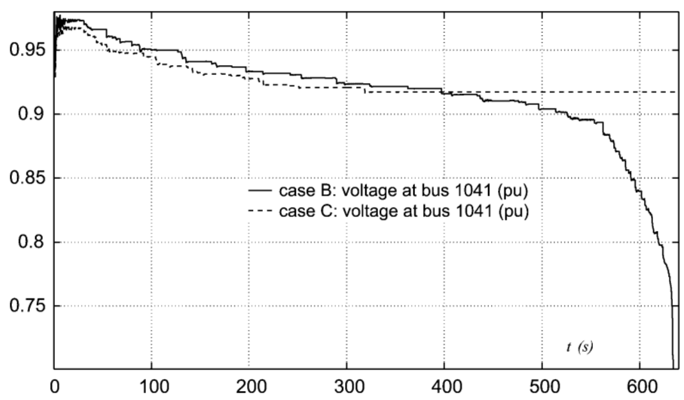
$$|\overline{Z}_{th}| = |\overline{Z}_L|$$



Methods based on observability in greater areas: More accurate. However, they require measurement communication, and – in most cases – essentially full coverage of PMUs, as the methods are based on voltage angles.

Plenty of other methods exist…

Voltage instability indicators



Marginally unstable case (B)

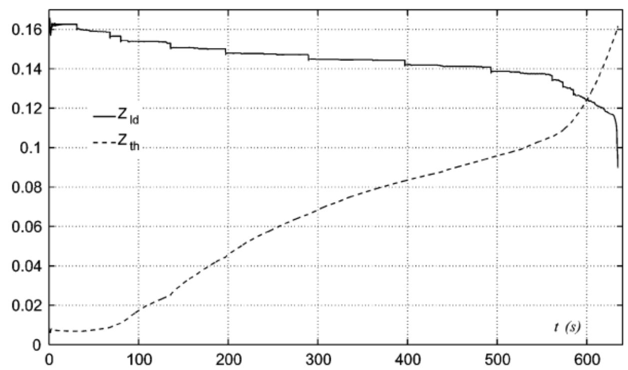


Fig. 21. Evolution of load (Z_{ld}) and Thévenin (Z_{th}) impedances; Case B.

Indication using Thévenin impedance matching

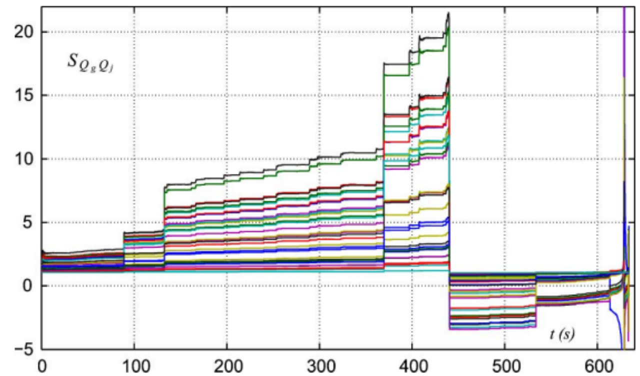
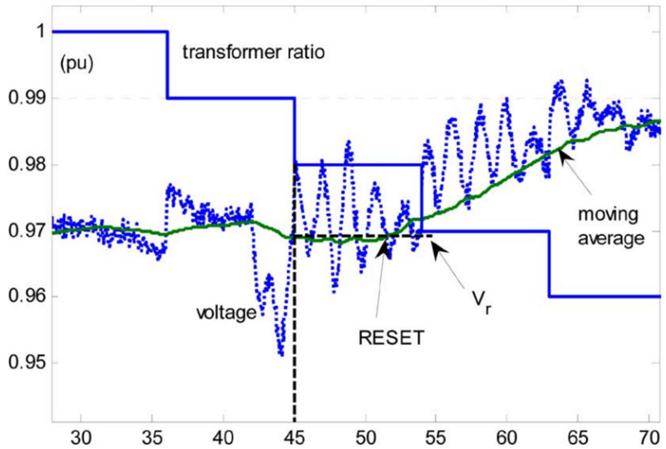


Fig. 5. Case B: sensitivities $S_{Q_g Q_j}$ at various buses.

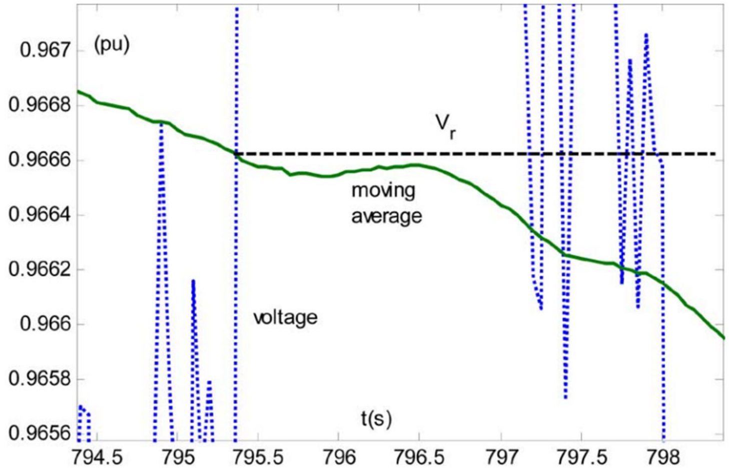
Indication with a more sophisticated method

LIVES algorithm

- **L**ocal **I**dentification of **V**oltage **E**mergency **S**ituations
  - presented by Thierry van Cutsem and Costas D. Vournas in 2008 [1]
- Based on the principle that a tap change in an OLTC that aims to *increase* the voltage on the secondary side, but actually results in a *decreased* voltage on the secondary side, is an indicator of system instability.
- Uses moving averages of the measured voltage on the secondary side to detect impending voltage collapses. The window size is the time constant for the tap changer.



No collapse



Impending collapse

[1] *Local Identification of Voltage Emergency Situations*. Van Cutsem, T., and Vournas, C. IEEE Transactions on Power Systems, vol. 23, no. 3, August 2008.


Methodology
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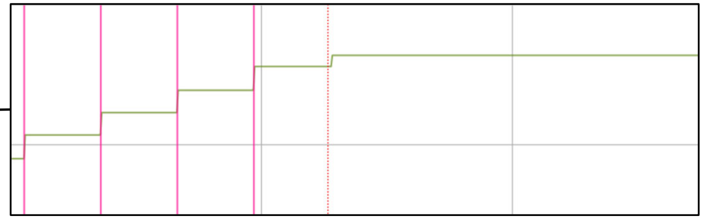
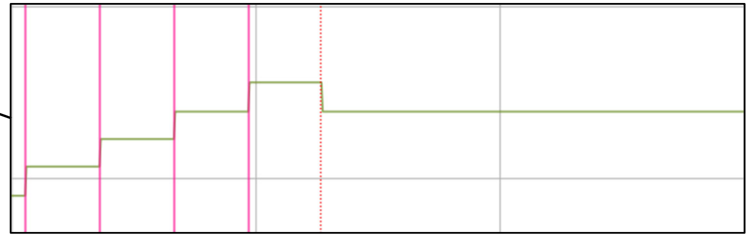
How we used the LIVES algorithm

- Instability detection
- Blocking the automation
- Back-stepping the OLTC

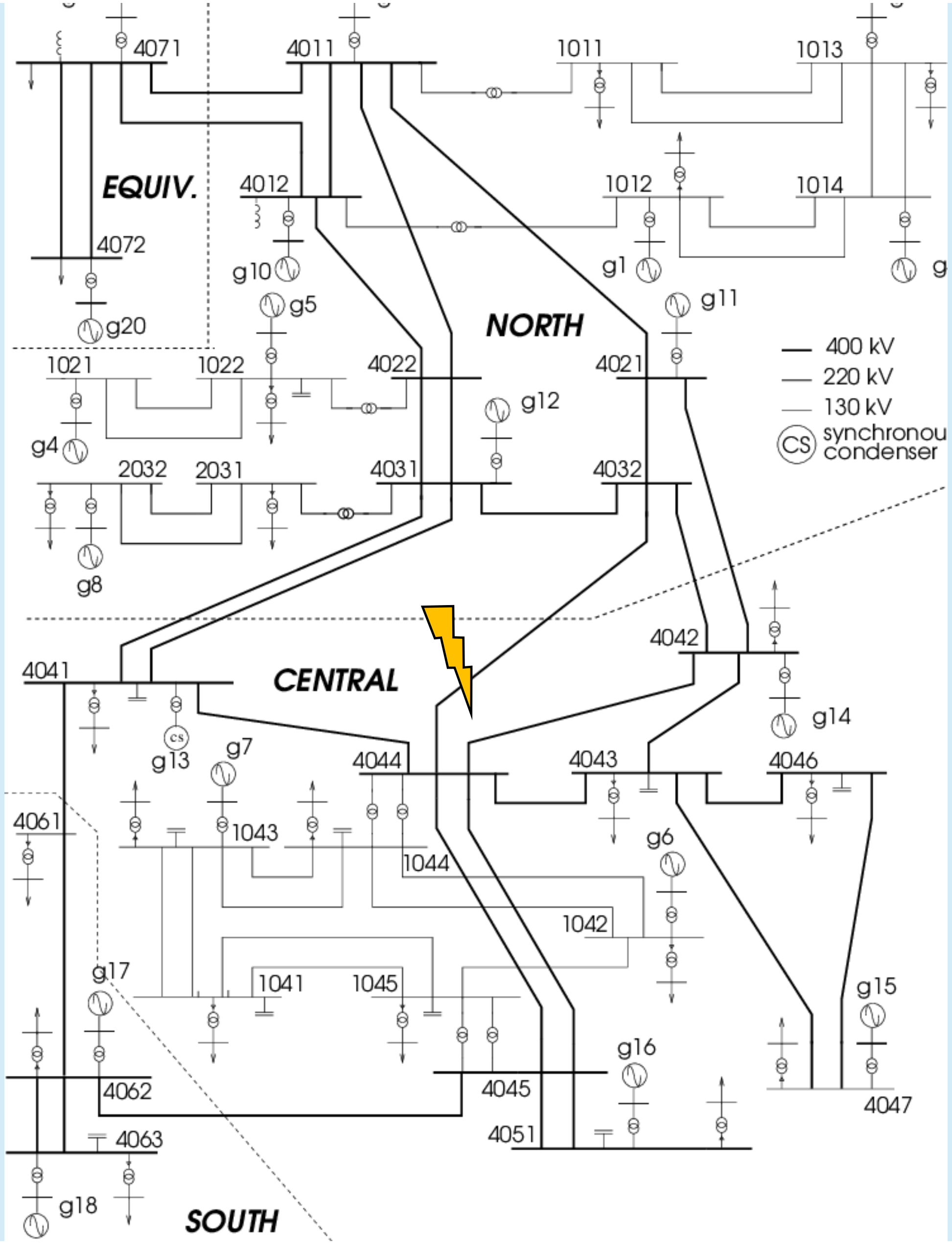




Methodology

- **Stage I**
  - Introductory simulations and algorithm development/tweaking in the IEEE Nordic32 Grid were conducted in PSS®E.
  - An N-1 fault was simulated

- Stage II
  - Simulations in our PSS®E grid model
  - Two simulated cases: one marginally stable, and one marginally unstable
  - Peak load scenario combined with subsequent faults (in total an N-3 scenario).



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Methodology

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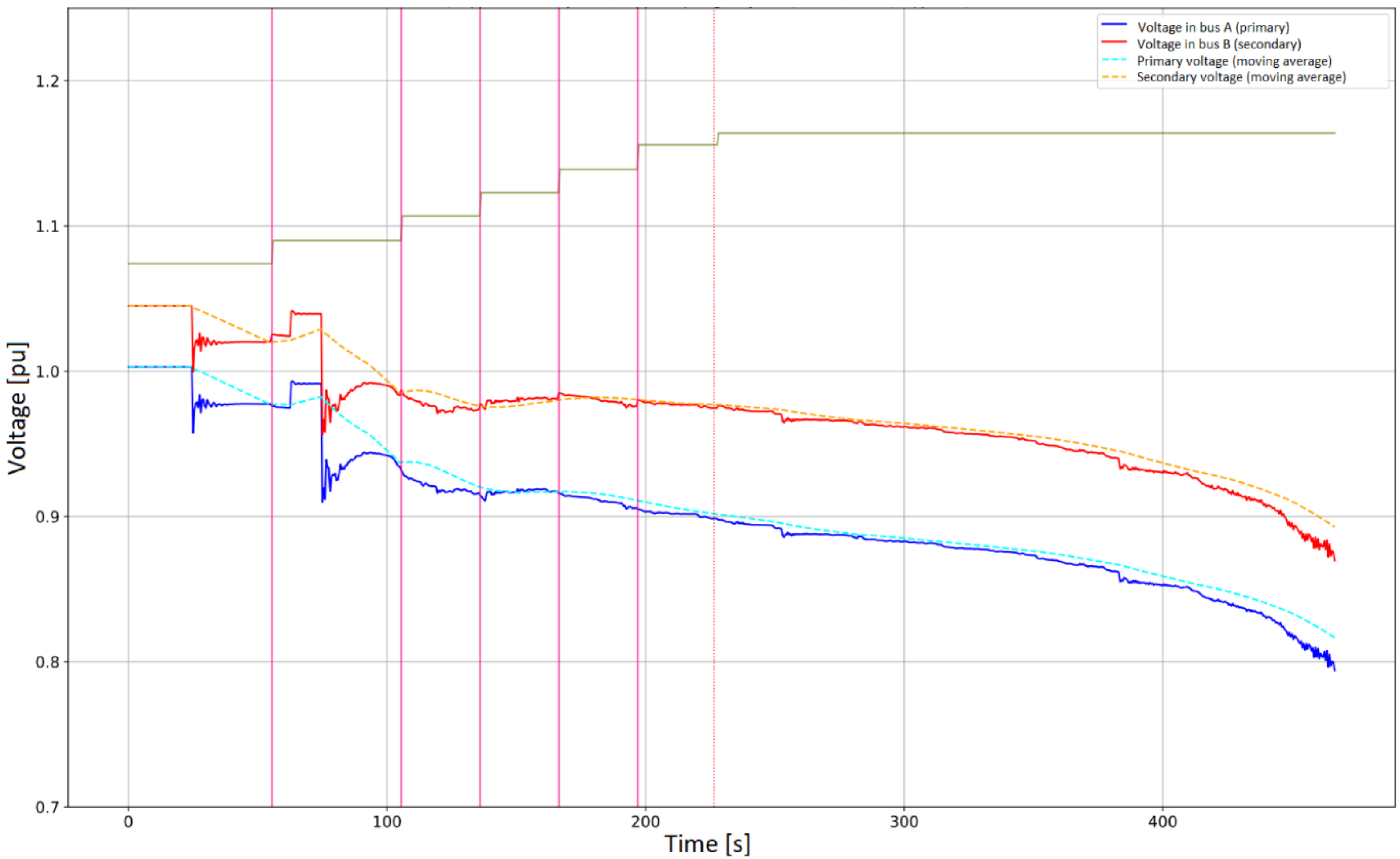
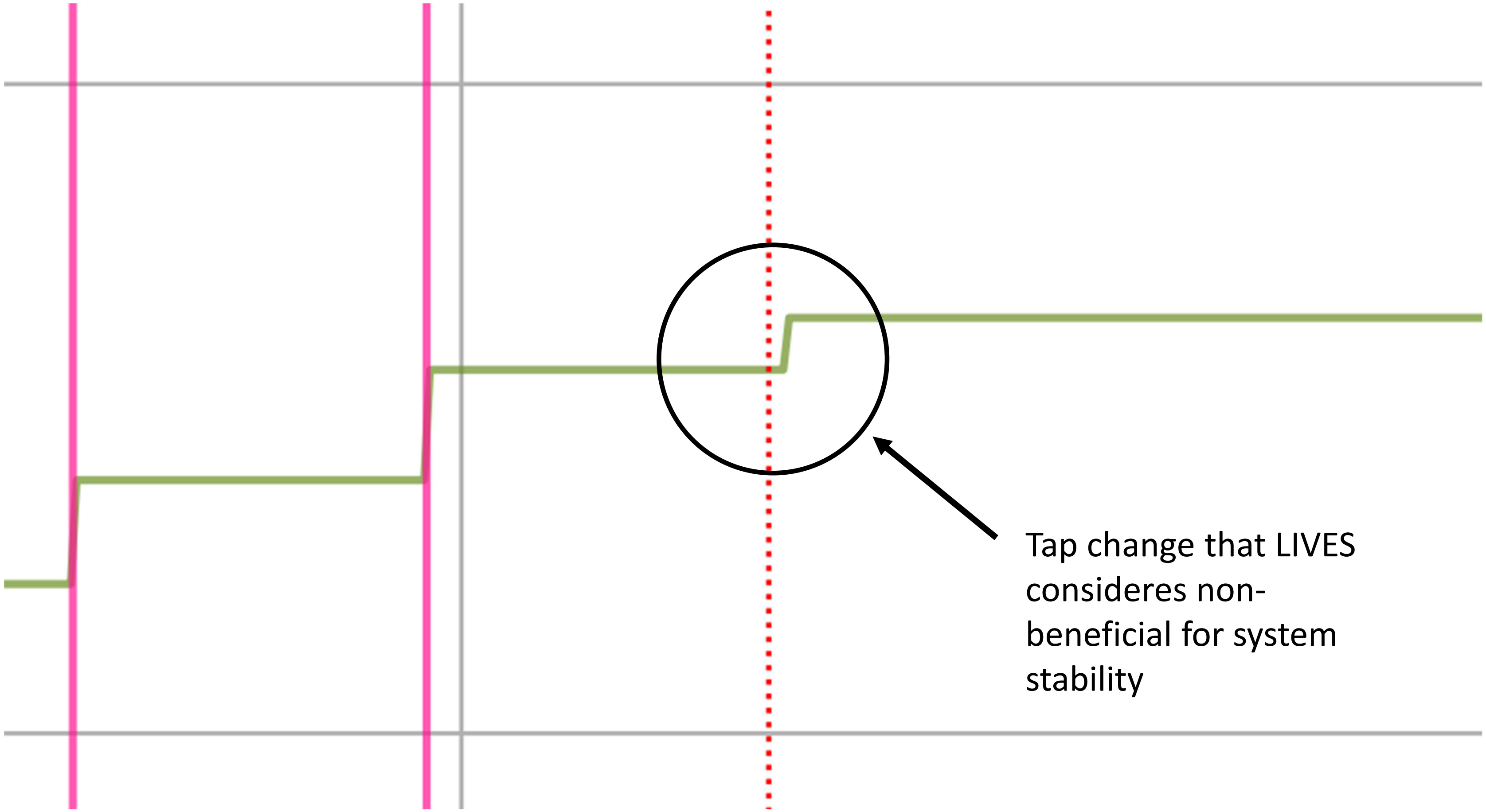
Results

Scenario A: Results (marginally unstable)

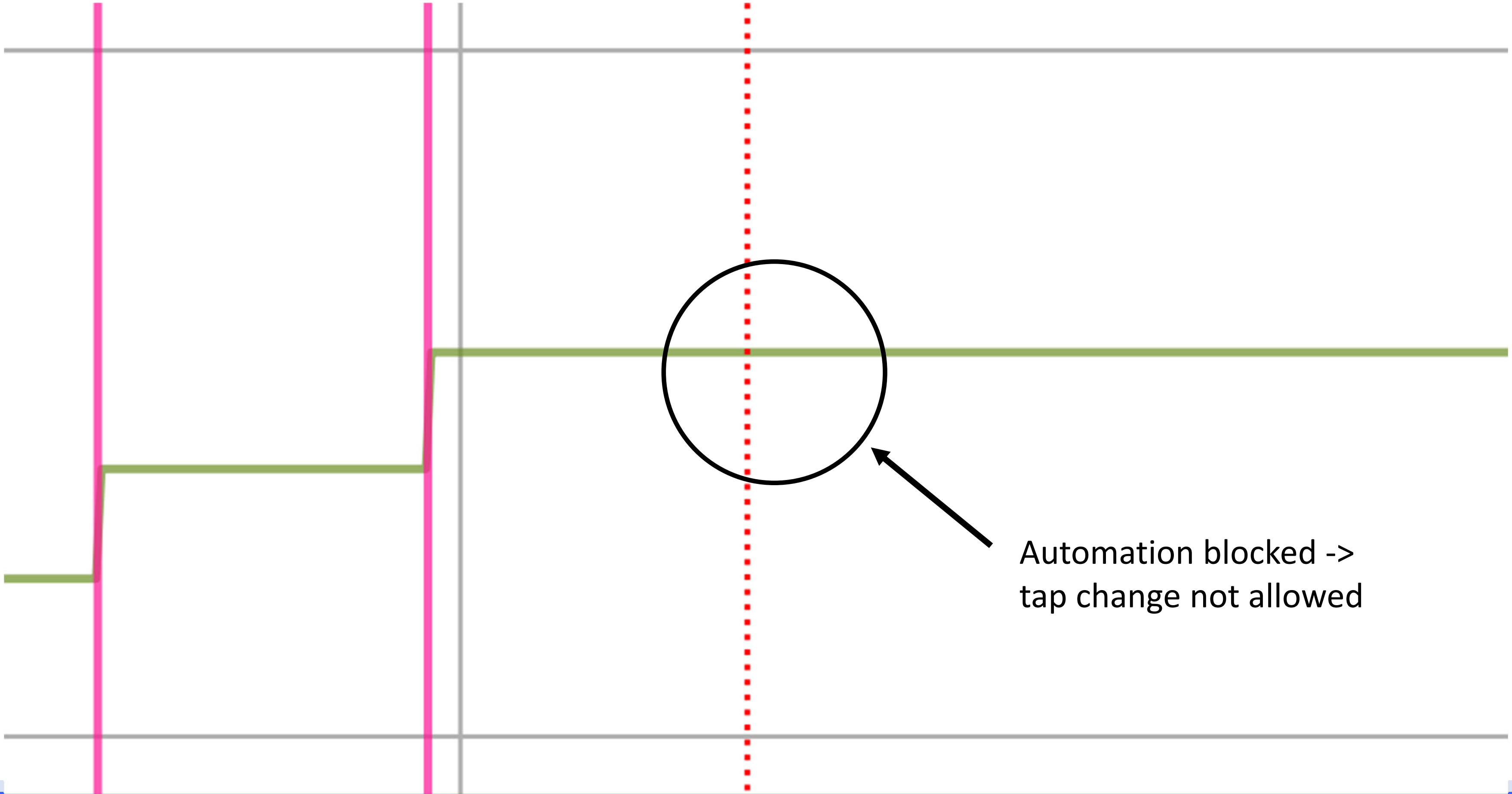


Scenario A: Results (marginally unstable)



Tap change that LIVES consideres non-beneficial for system stability

Scenario A: Results (marginally unstable)



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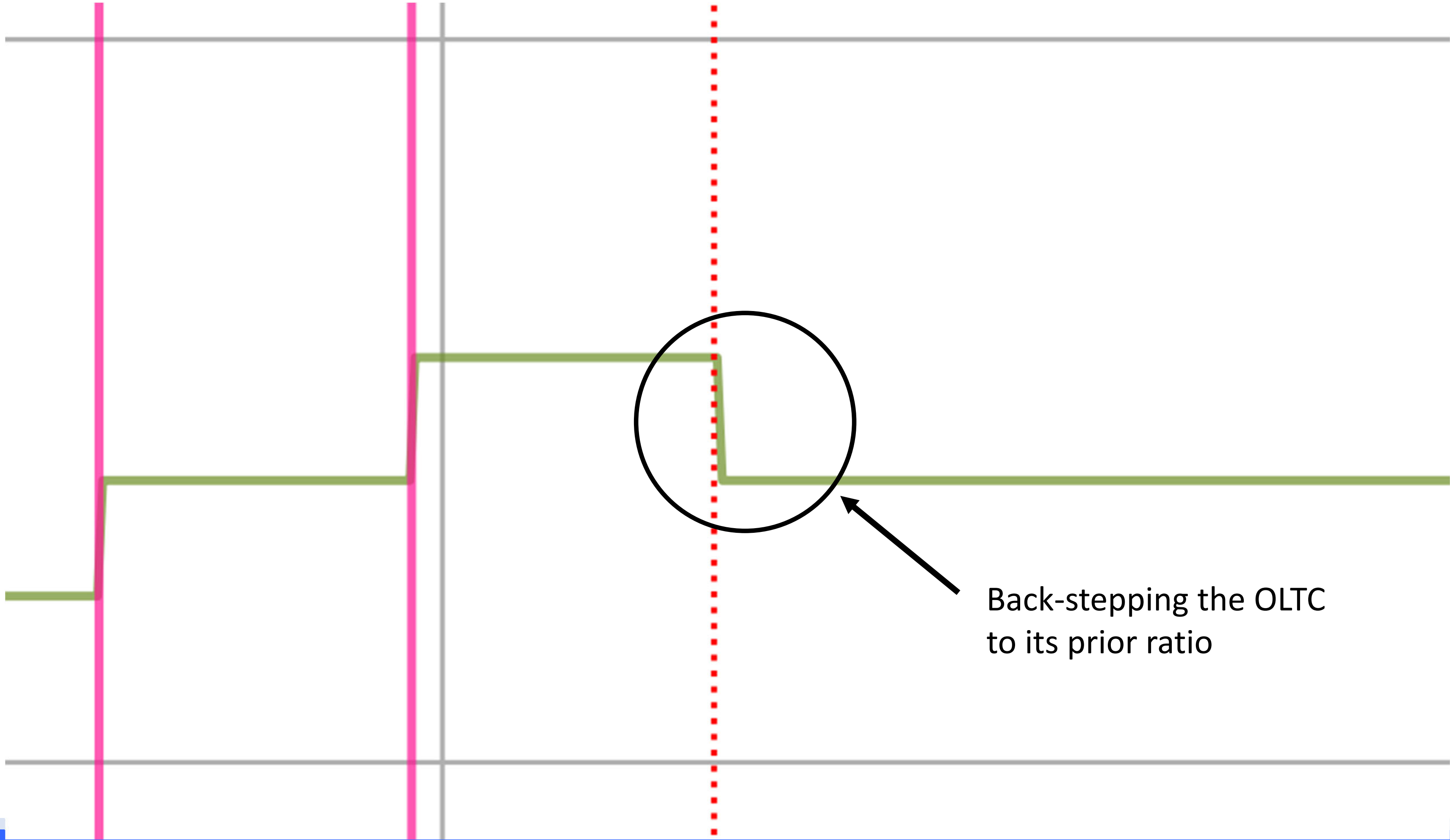
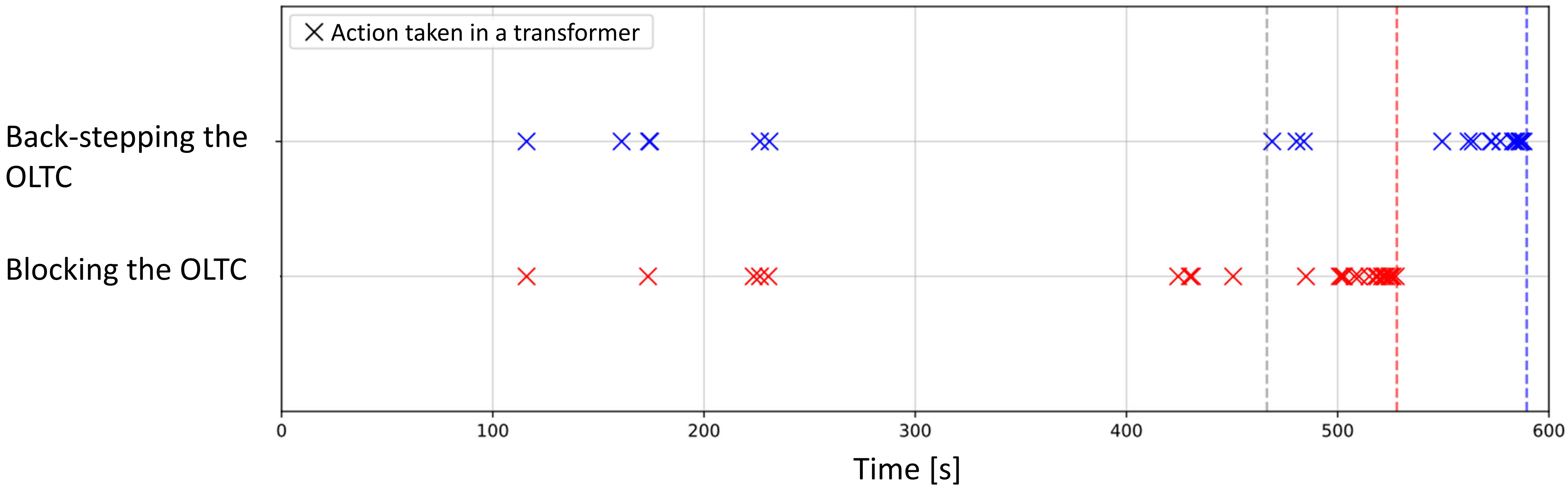


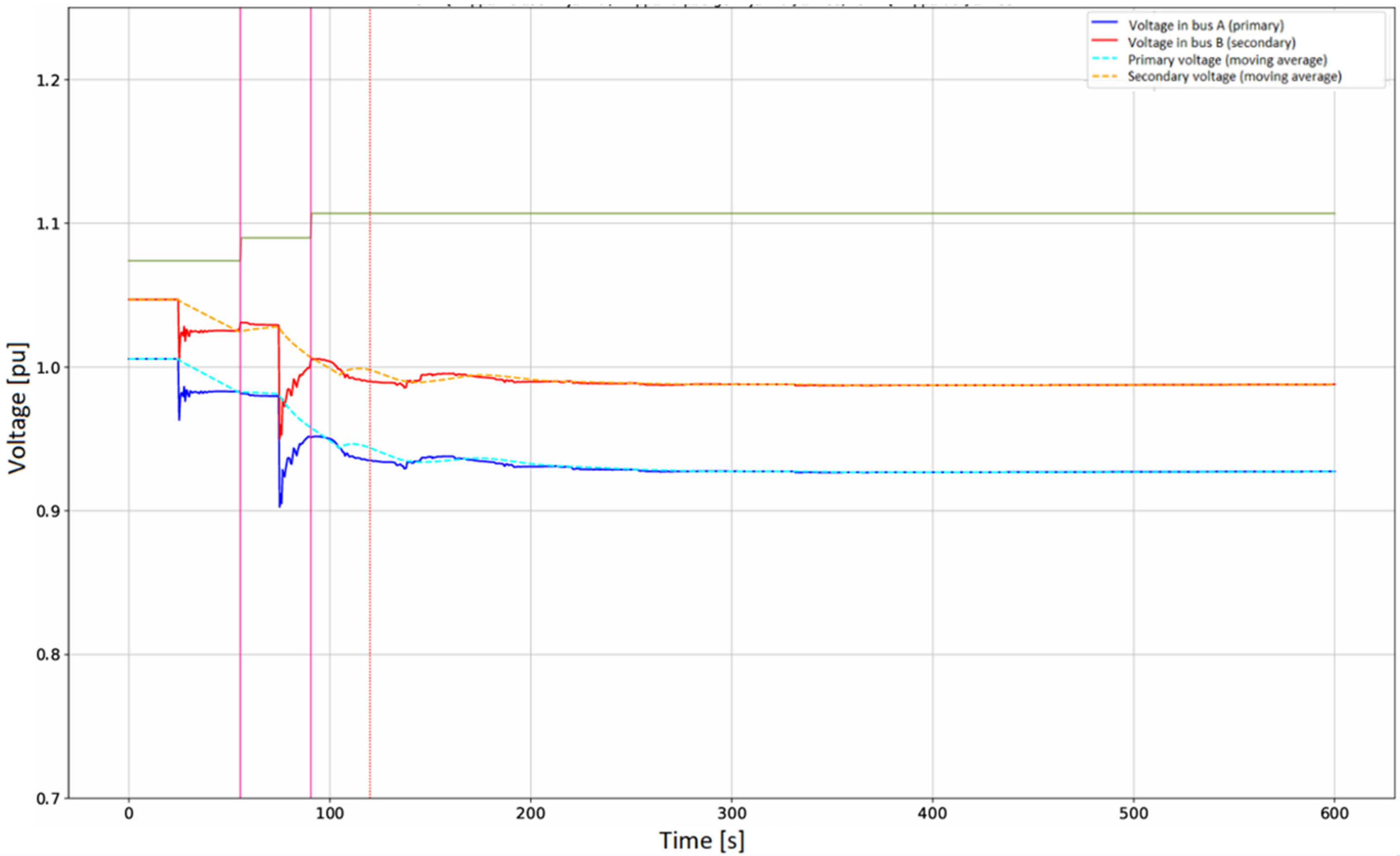
Scenario A: Results (marginally unstable case)

Action taken upon LIVES alarm	Time until collapse	ΔT [s]
None	467 seconds	-
Blocking the OLTC automation	528 seconds	+61
Back-stepping the OLTC	589 seconds	+122

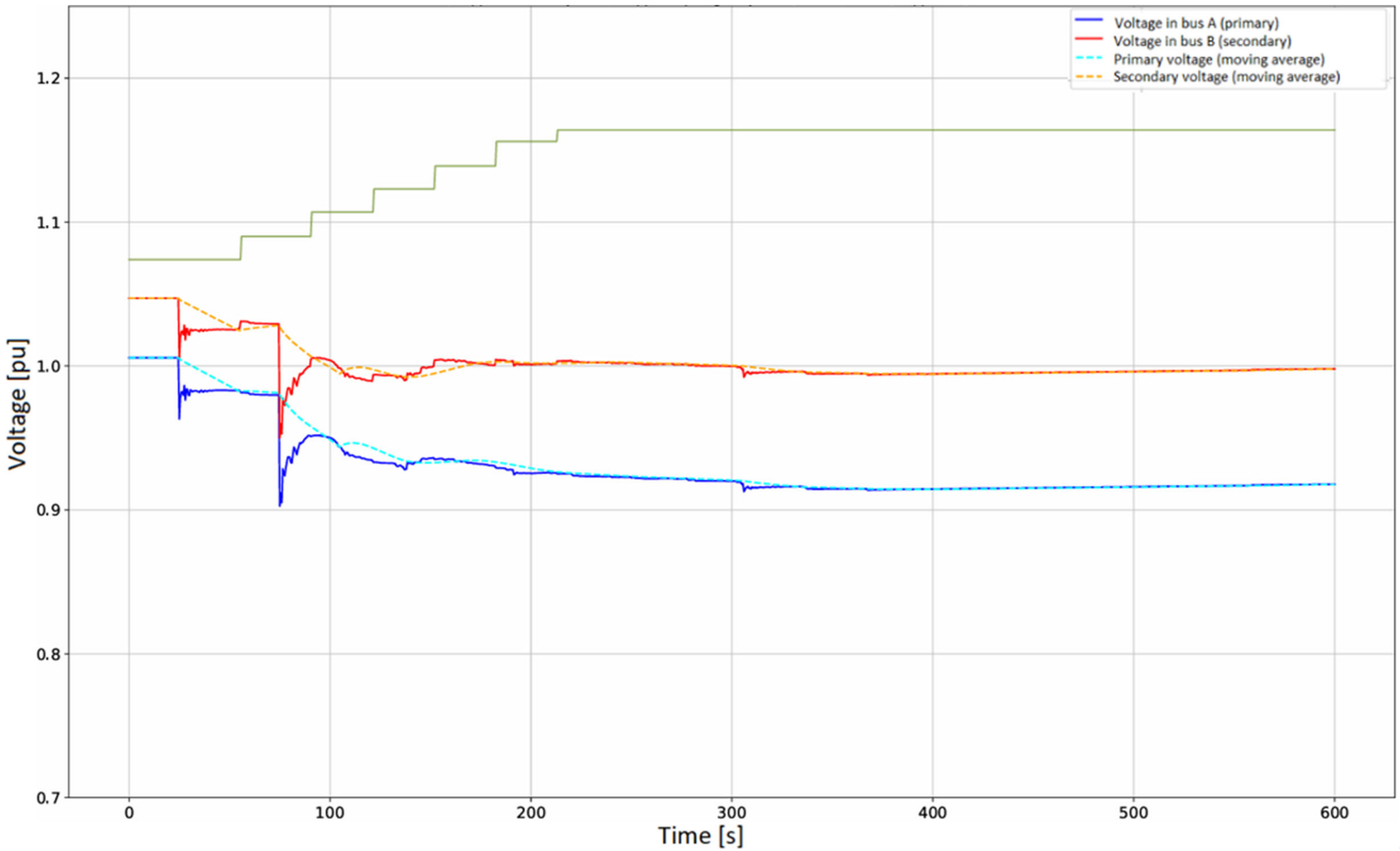
Scenario A: Usefulness of blocking vs back-stepping



Scenario B: Results (marginally stable) with blocking

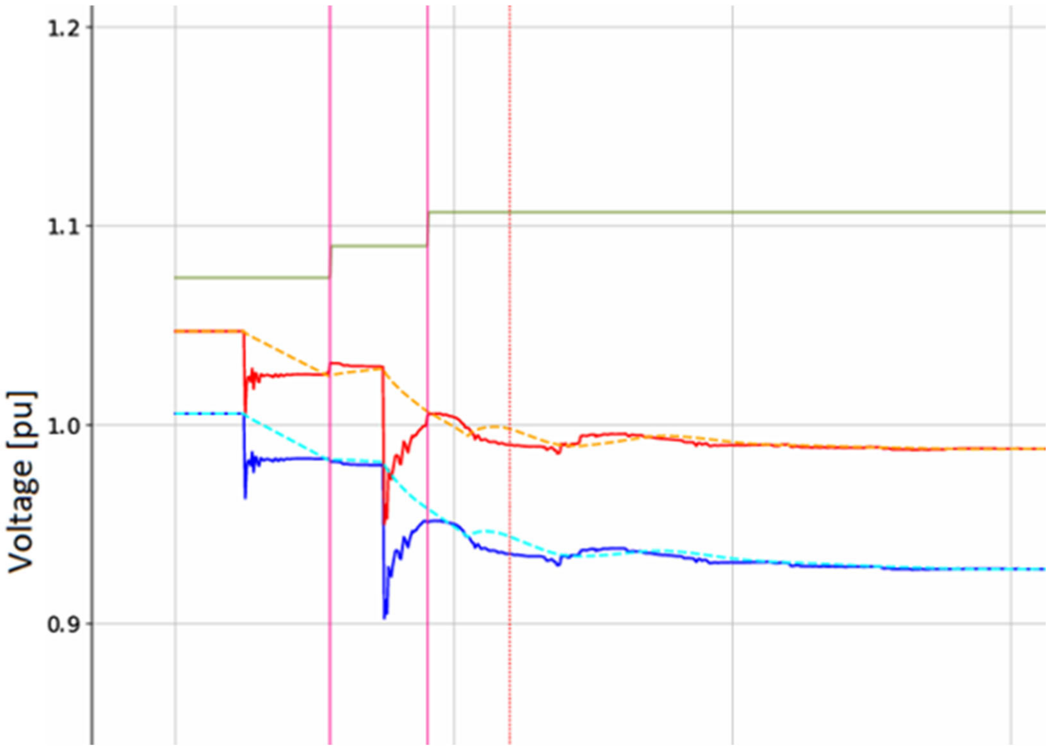


Scenario B: Results (marginally stable) without blocking



Scenario B: Results (marginally stable)

4 extra, non-harmful tap changes performed



Conclusions

Conclusions

- The LIVES algorithm *can* be used to delay voltage collapses in actual grids by performing local actions in the OLTC transformers
  - However, it cannot singlehandedly save an unstable system, but might reduce the need for other system protection schemes (e.g. load shedding)
  - Furthermore, it sometimes erroneously indicates instability in stable systems
- Back-stepping is more efficient than simply blocking
  - However, it is also more intrusive on DSO voltages
- The window size of the moving average plays a critical role (shorter timespans seem to be more efficient)
  - However, it is governed by the time constants in the actual transformers

- Ideas for future research:
  - Tweaking the LIVES algorithm
  - Using other voltage instability indicators for performing actions such as blocking OLTCs or back-stepping


Thank you for your attention!

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