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Paper ID 903

Fault Location in Transmission Systems with Large Scale Inverter-Based Resource (IBR) Integration: Challenges and Future Trends

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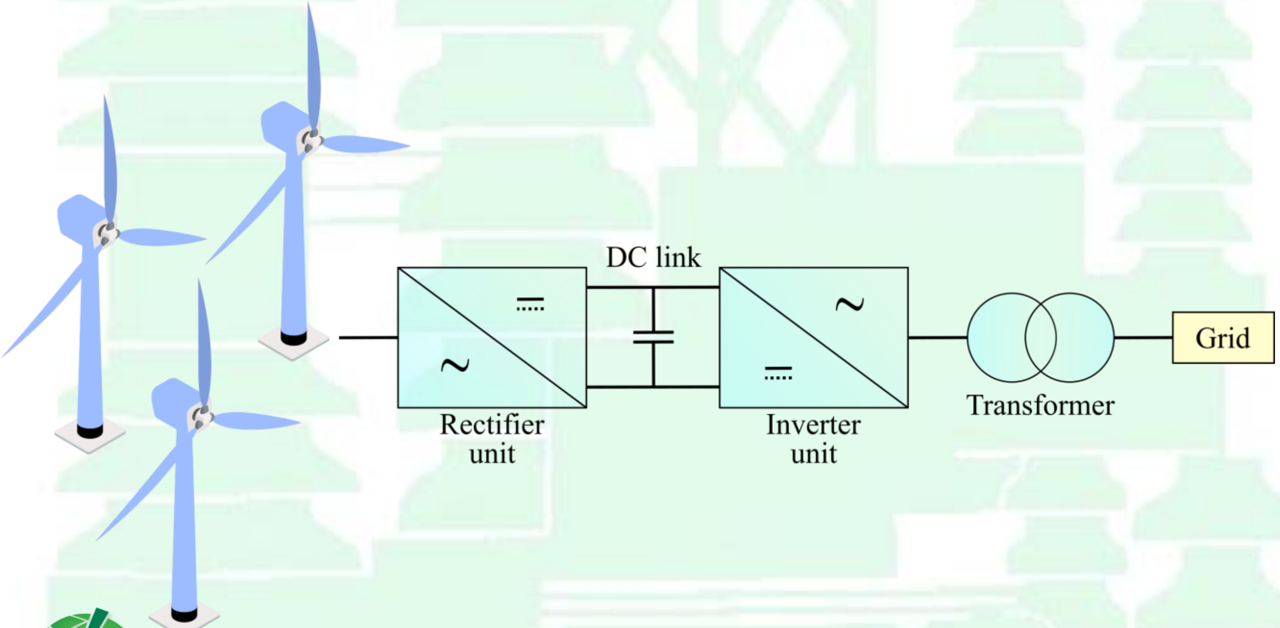
Introduction

- **The environmental issues associated with the use of fossil fuel-based sources have led the world to search for cleaner alternatives to generate electricity**
    - Renewable sources have appeared as promising solutions

- **Large-scale integration of such inverter-based resources (IBRs)**

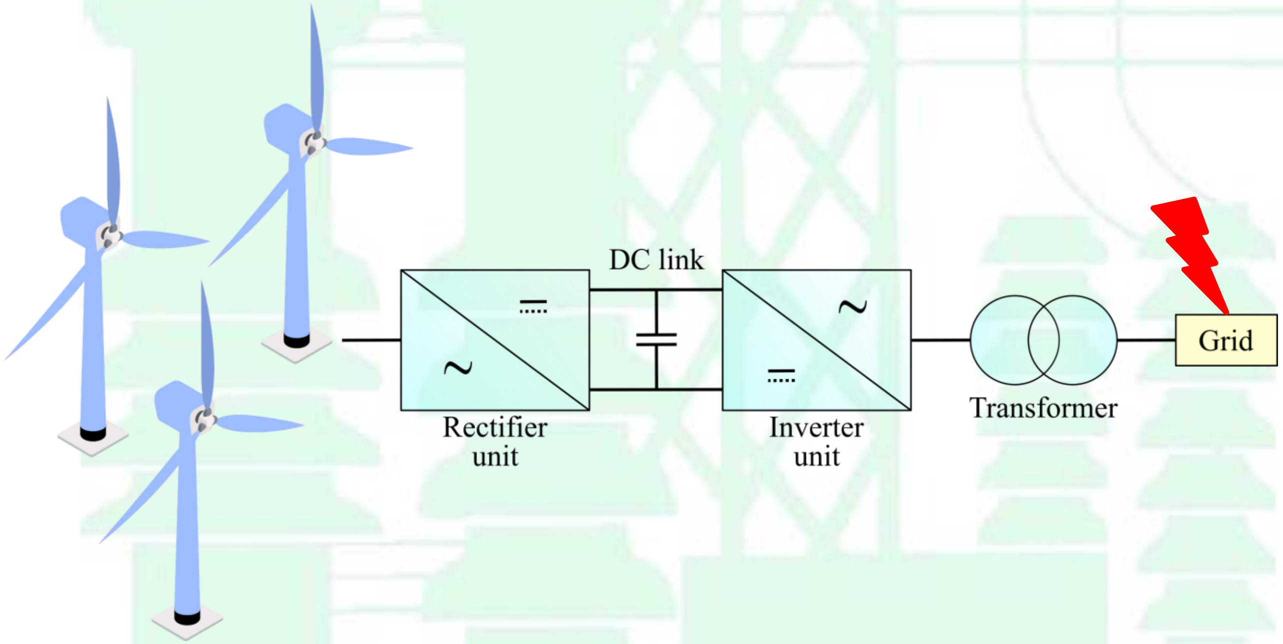


New challenges to the system operation

Intermittent behavior, inherent low inertia and control-dependent characteristics

Impact the performance of protective relays and fault locators

Introduction



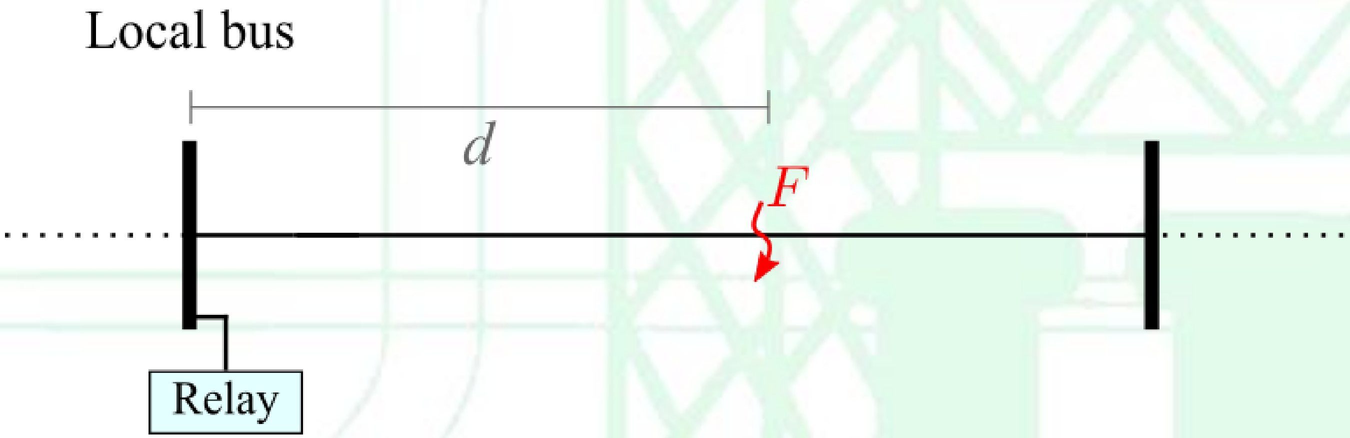
- **Fault location needs to be properly identified**
- **Solutions have moved toward the development of reliable and faster impedance- and TW-based techniques**
    - Their performances are well-investigated in conventional (high-inertia) power grids
    - Impacts on lines interconnected by IBRs still demand more investigations

What are the impacts on phasor estimation procedures?

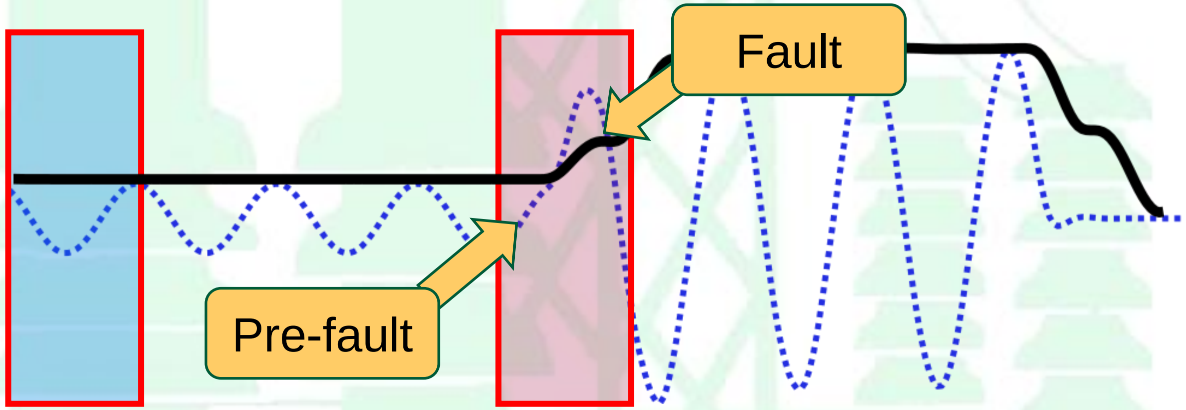
What are the impacts on the fault-induced TWs?

What is the performance of single-ended fault location functionalities?

Theory Background

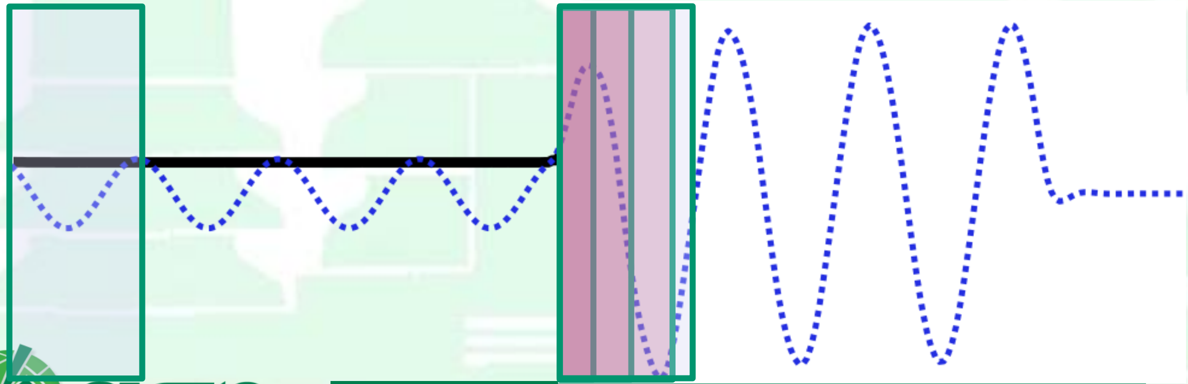


- **Phasor-Based Techniques**
  - Sliding data windows with fixed sizes



Transient period with pre- and post-fault samples

  - Sliding data windows with variable sizes

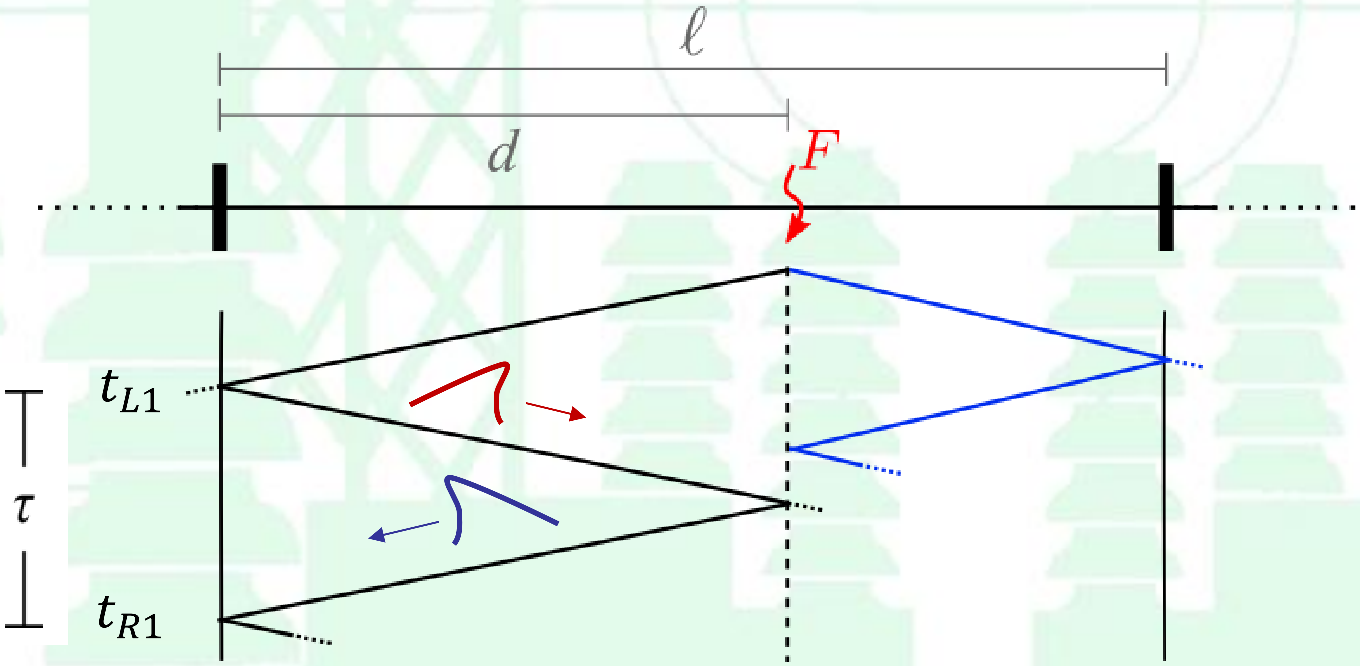


Speed up the phasor estimation process

$$d = \frac{im\left(\hat{V}_L \cdot \Delta\hat{I}_L^*\right)}{im\left(Z_{L1} \cdot \hat{I}_L \cdot \Delta\hat{I}_L^*\right)}$$

Theory Background

- **TW-based Technique**

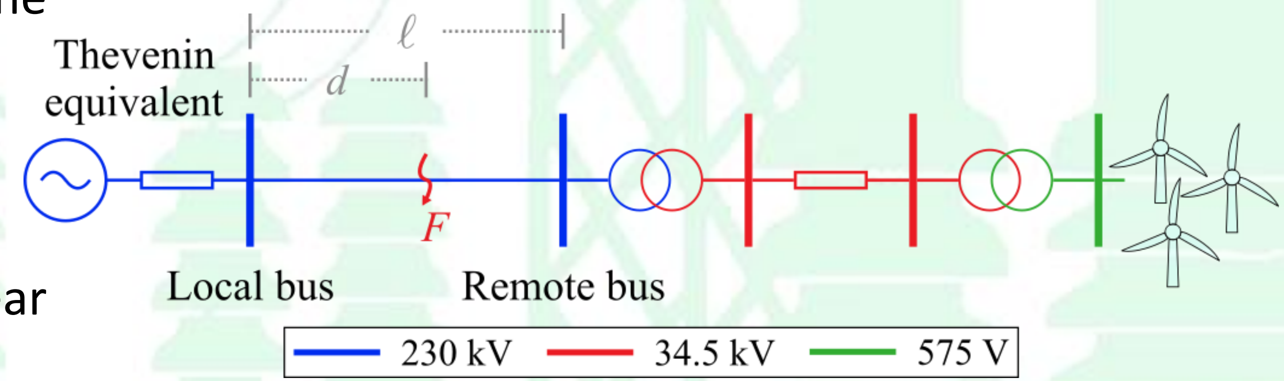


$$d_1 = \frac{v_1 \cdot \tau \cdot \Delta t}{2}$$

$$\varphi(\tau) = \frac{1}{\Delta k_{obs}} \sum_{k=1}^{\Delta k_{obs}} \left[S_{backward}(k\Delta t + \tau) \cdot S_{template}(k\Delta t) \right]$$

Methodology of Evaluation

- **230 kV/60 Hz test system adjusted with parameters taken from a real Brazilian network**
  - Faults applied at 15 km and 135 km of the transmission line ($\ell = 150\ km$)
  - Frequency-dependent line model
  - Full-converter-based wind generators with nonlinear elements and associated controls
  - Busbar and transformers stray capacitances of 0.1 µF
  - Since the main idea relies on evaluating the impact of RESs integration on fault location techniques, an average wind speed equal to 15 m/s was considered

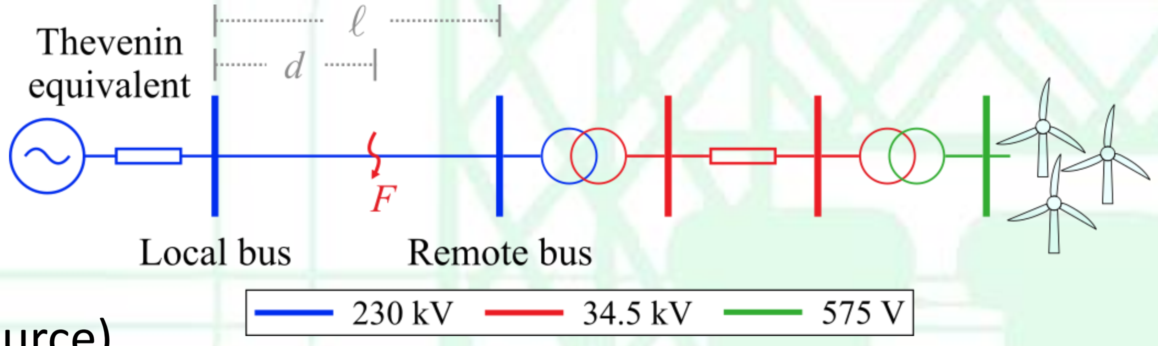


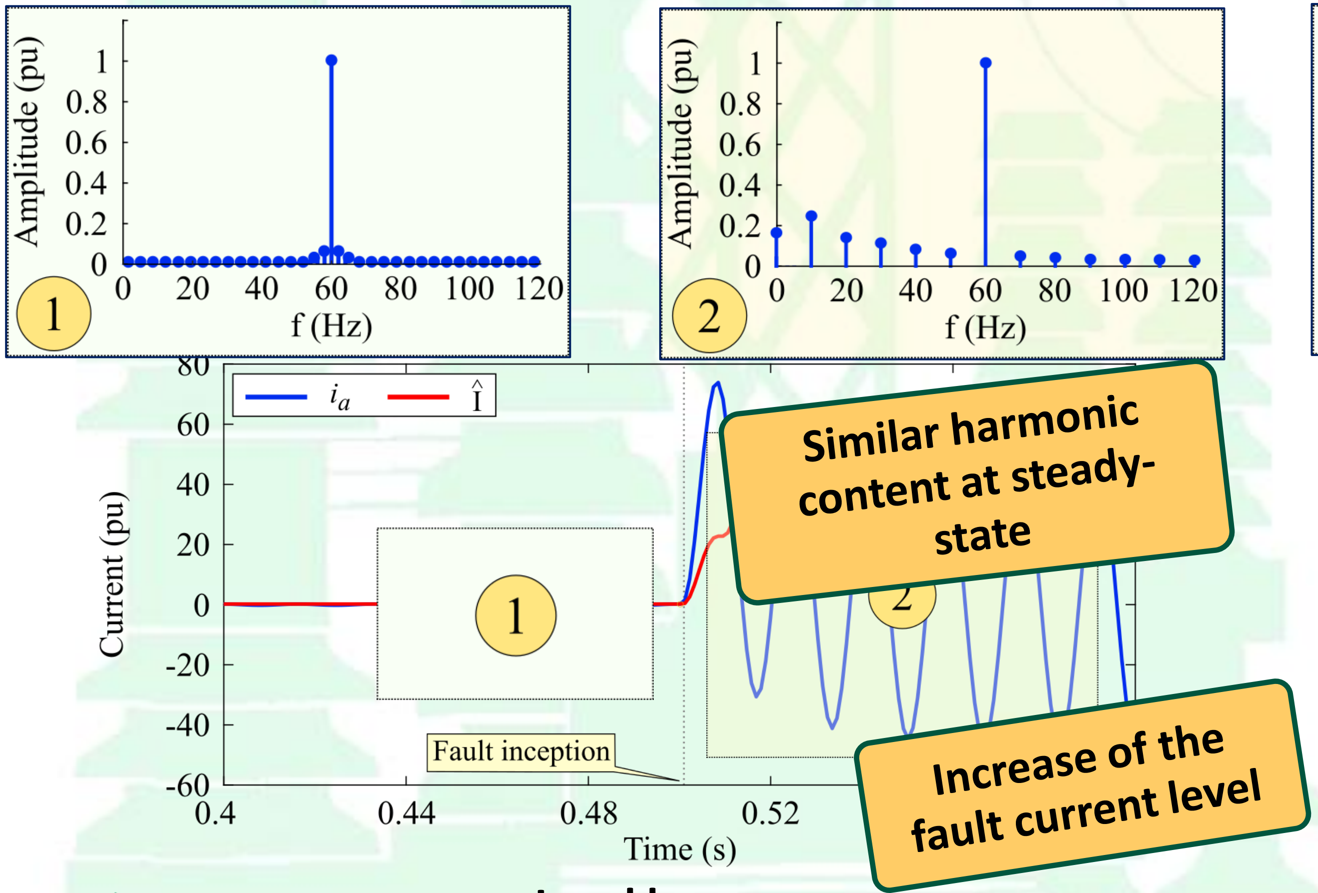
960 Hz for phasor-based approach

1 MHz for TW-based method

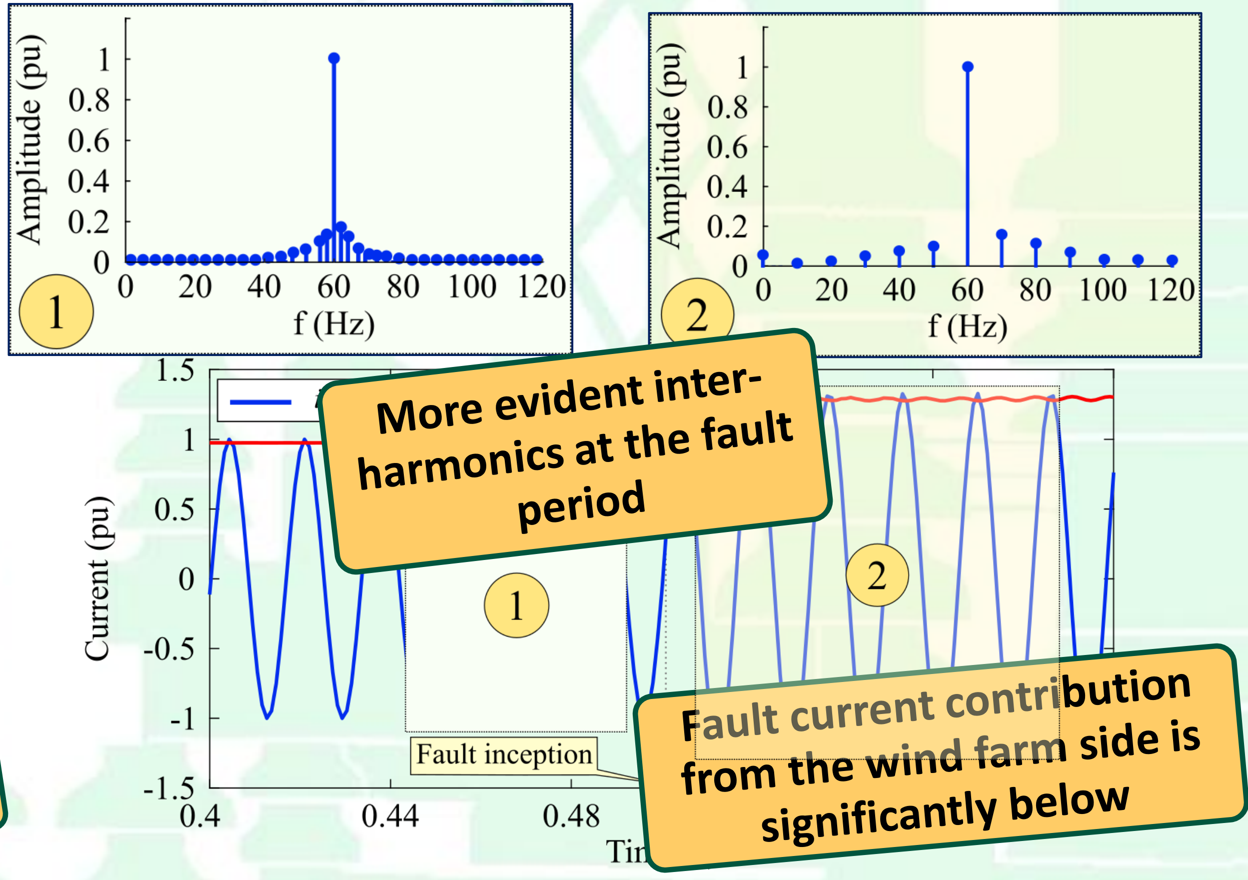
Analysis and Results

- **Phasor-based analysis**
  - 15 km away from the local bus (conventional source)





Local bus

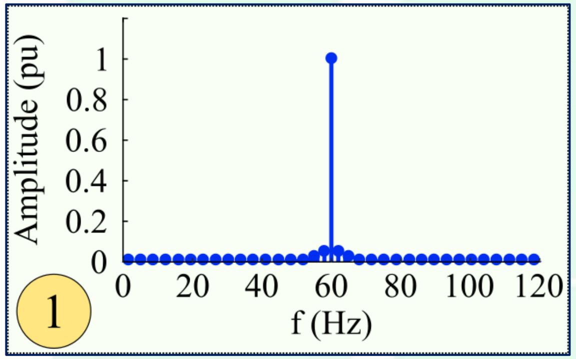


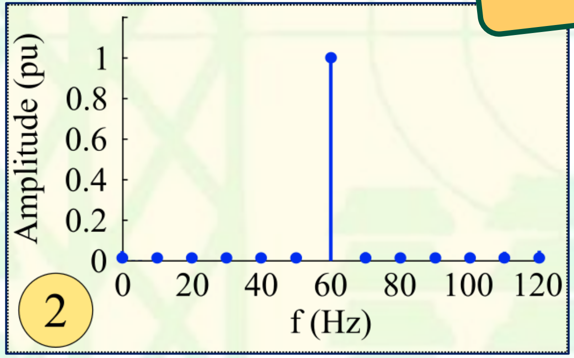
Remote bus

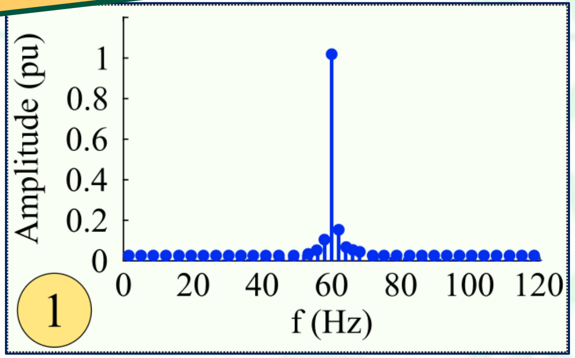
Analysis and Results

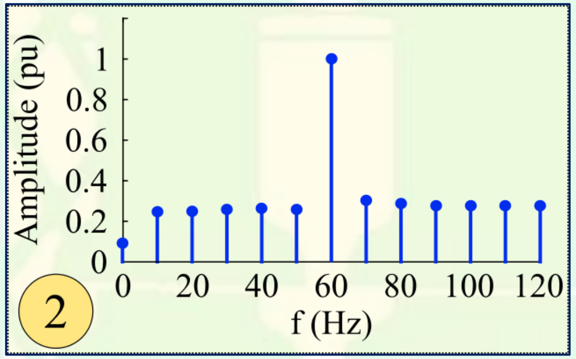
Similar harmonic content at steady-state

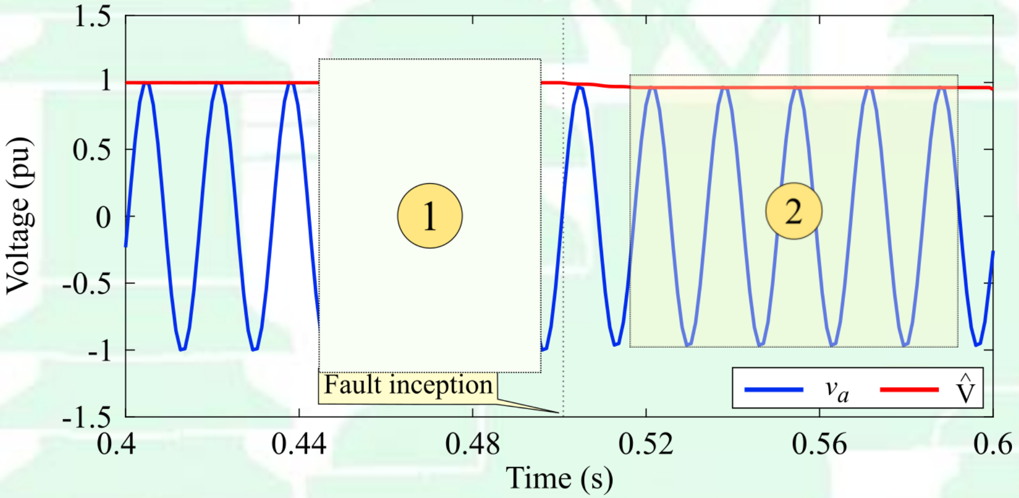
More evident subharmonics at the fault period



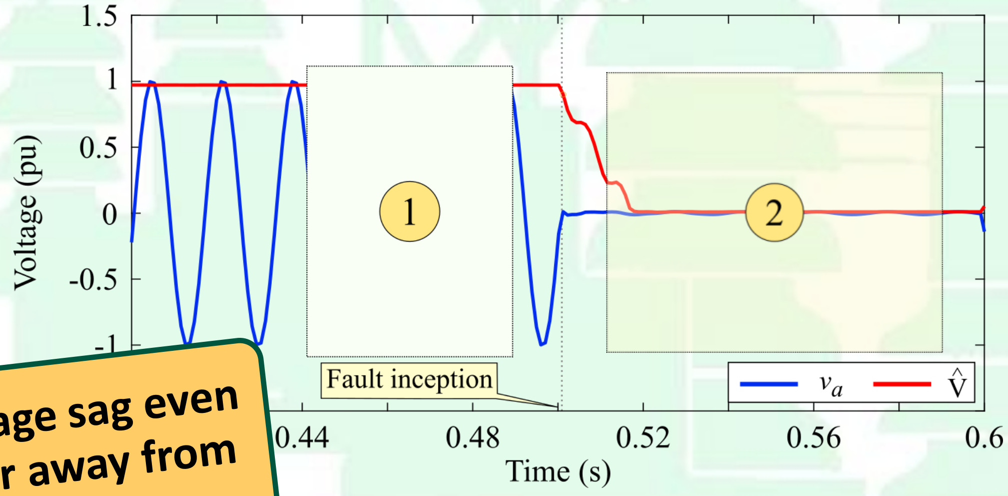








Local bus

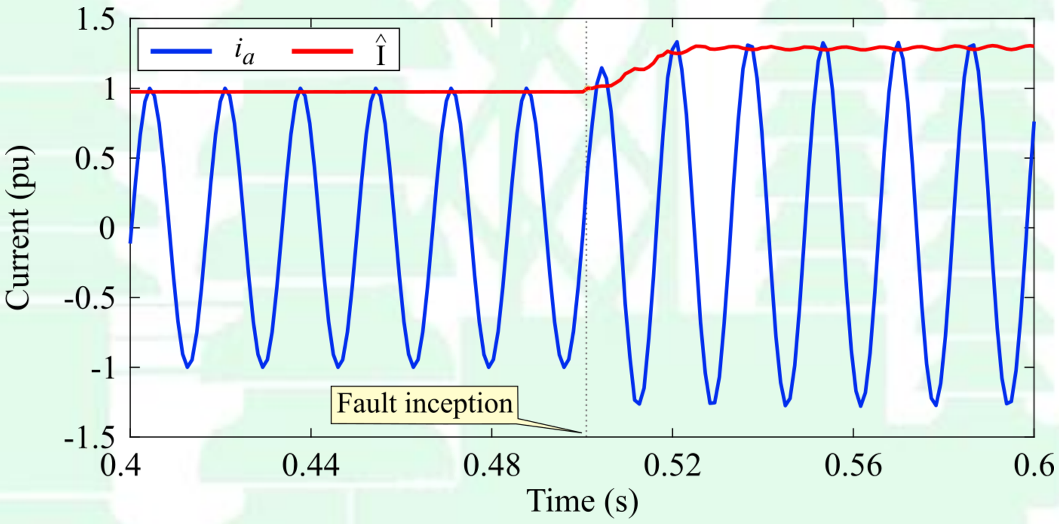


Remote bus

Atypical voltage sag even for a fault far away from the wind farm bus

Analysis and Results

- **Phasor-based analysis**
  - 135 km away from the local bus (conventional source)



Remote bus

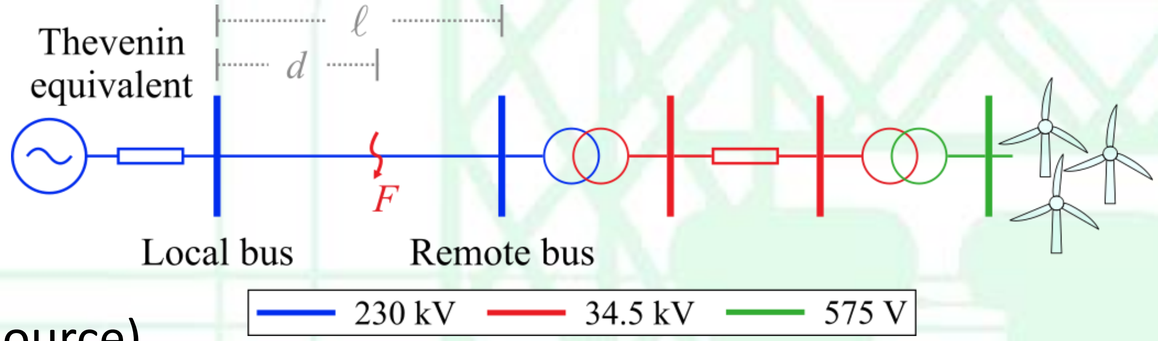
- Evaluation of different fault location scenarios

Higher number of cycles used as input data does not lead to better fault location estimations

Errors can fall into a wider range than the ones expected for impedance-based methods

Analysis and Results

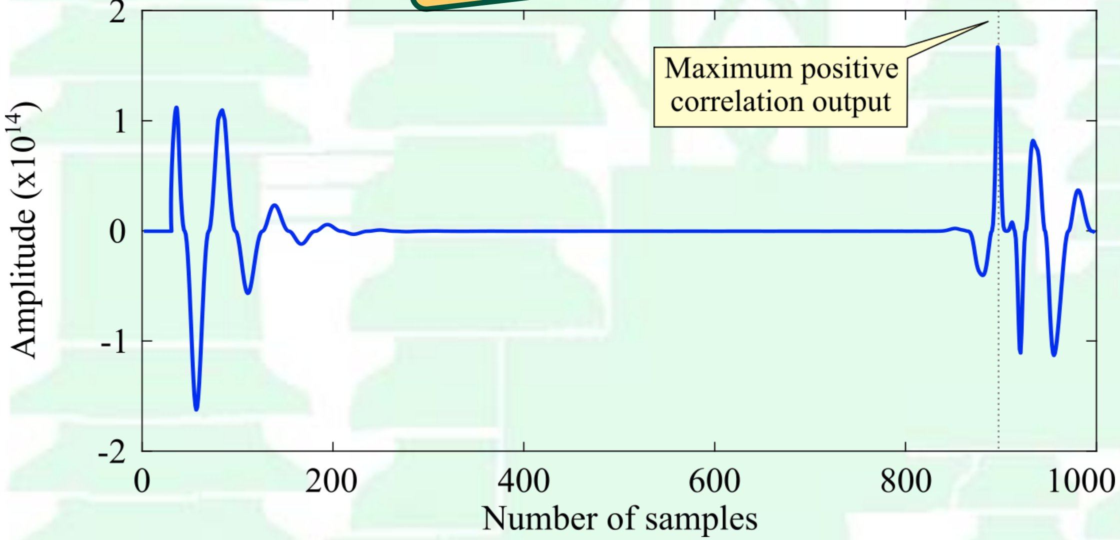
- **TW-based analysis**
  - 135 km away from the local bus (conventional source)



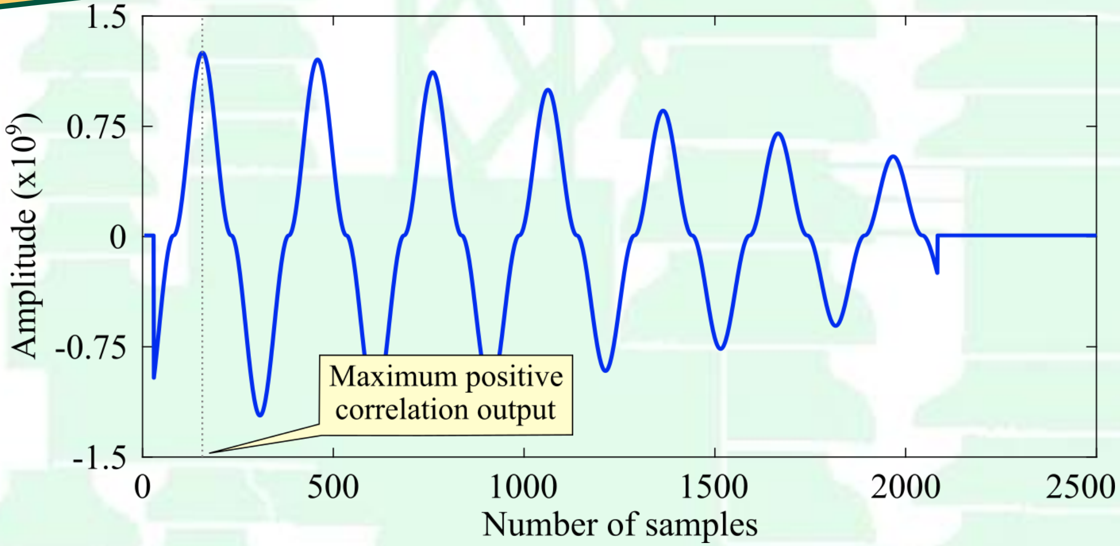
More evident peaks

Impact of low frequencies

Difficult to estimate the fault-induced reflected TW



Local bus



Remote bus

Conclusions

- **Better estimations for the measurements taken from the conventional source bus**
  - For both phasor- and TW-based methods
- **Atypical fault responses induced by the wind farm dynamics have resulted in higher errors**
  - Errors quite higher than the ones expected for both fault location techniques
- **Need to develop strategies more immune to the effects of the control-dependent wind farm dynamics and low fault current contributions**
  - Multi-method impedance-based techniques
  - For TW-based approaches, the identification of fault-induced reflected surge is still a challenge for conventional grids, but its detection at IBR side is more difficult
  - Use of communication links for double-ended methods

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4 CONPROVE

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Thank you!

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