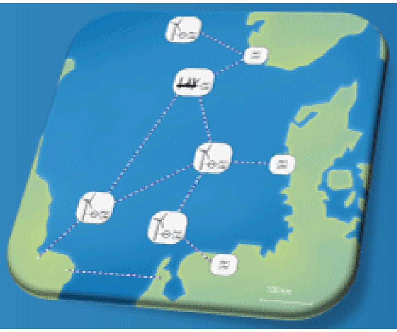

ProOfGrids

Protection and Fault Handling in Offshore HVDC Grids

Non-unit fault detection method in multi-terminal HVDC system based on the high frequency transients on travelling waves

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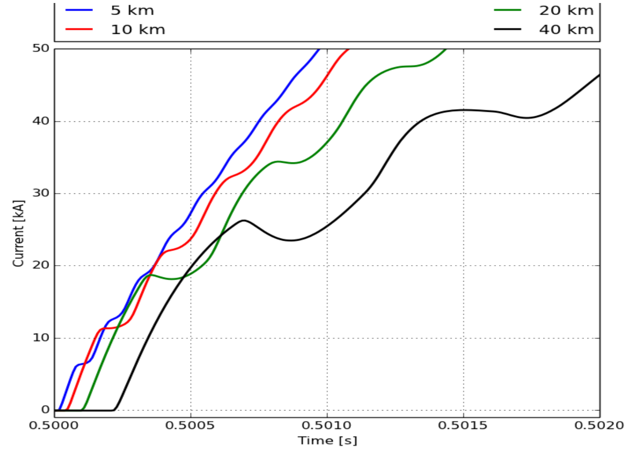
Introduction

- In the last decade, Multi-terminal HVDC (MTDC) systems have gained much attention. This solution suits for certain applications such as **the large-scale integration of remote renewable sources**, or the interconnection of asynchronous ac regions.
- One of the most desirable feature of meshed MTDC systems is the ability to increase the **reliability** of power transfer. MTDC can provide alternative transmission paths using the **protection system**.
- The main challenge is to produce a **fast** algorithm able to provide high **selectivity** on faults within its protection zone and discriminate faults outside its protection zone.
- The traditional fault detection algorithms in ac grids cannot be applied directly in dc grids.

Picture from http://www.gegridsolutions.com/

Fault detection scheme

This work propose a communication-less scheme that use the **discrete wavelet transform** to analyze the dc current **high frequency transients** contained in the travelling waves. Travelling waves are **high frequency electromagnetic impulses**.



Advantages with TWs

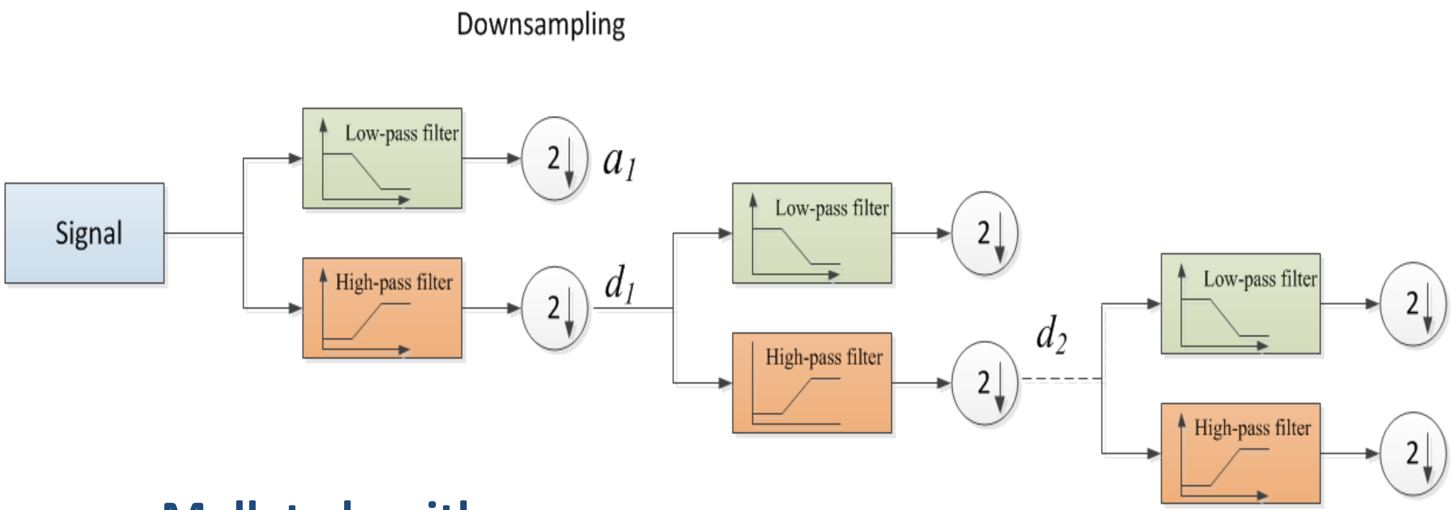
- TWs offer a fast response.
- In principle, TWs are insensitive to system topology, type of fault, fault resistance, or line parameters.
- They are less sensitive to noise.
- It can provide an accurate exact fault location

Disadvantages with TW

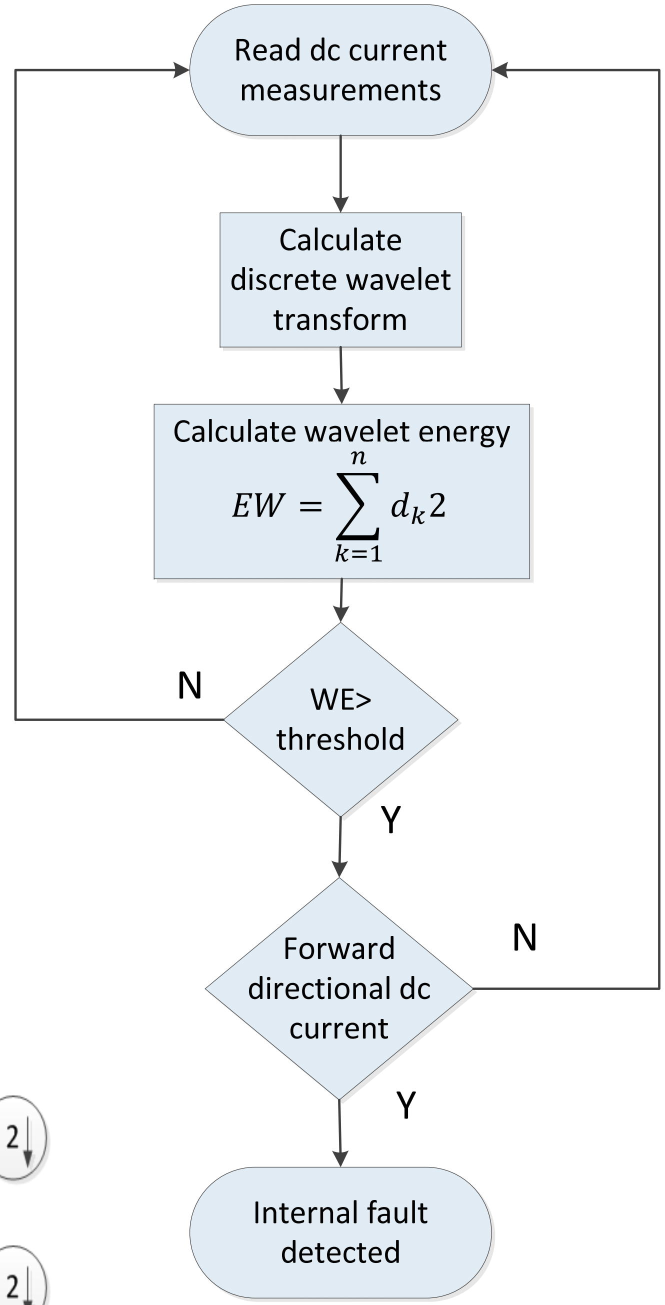
- It requires a high frequency sampling rate.
- In meshed configurations, fault detection is challenging

Fault detection scheme

The proposed fault detection algorithm is based on the **comparison of the magnitude of the high frequency transients** in the dc current at the measuring points of each relay.



Mallat algorithm.



Fault detection scheme

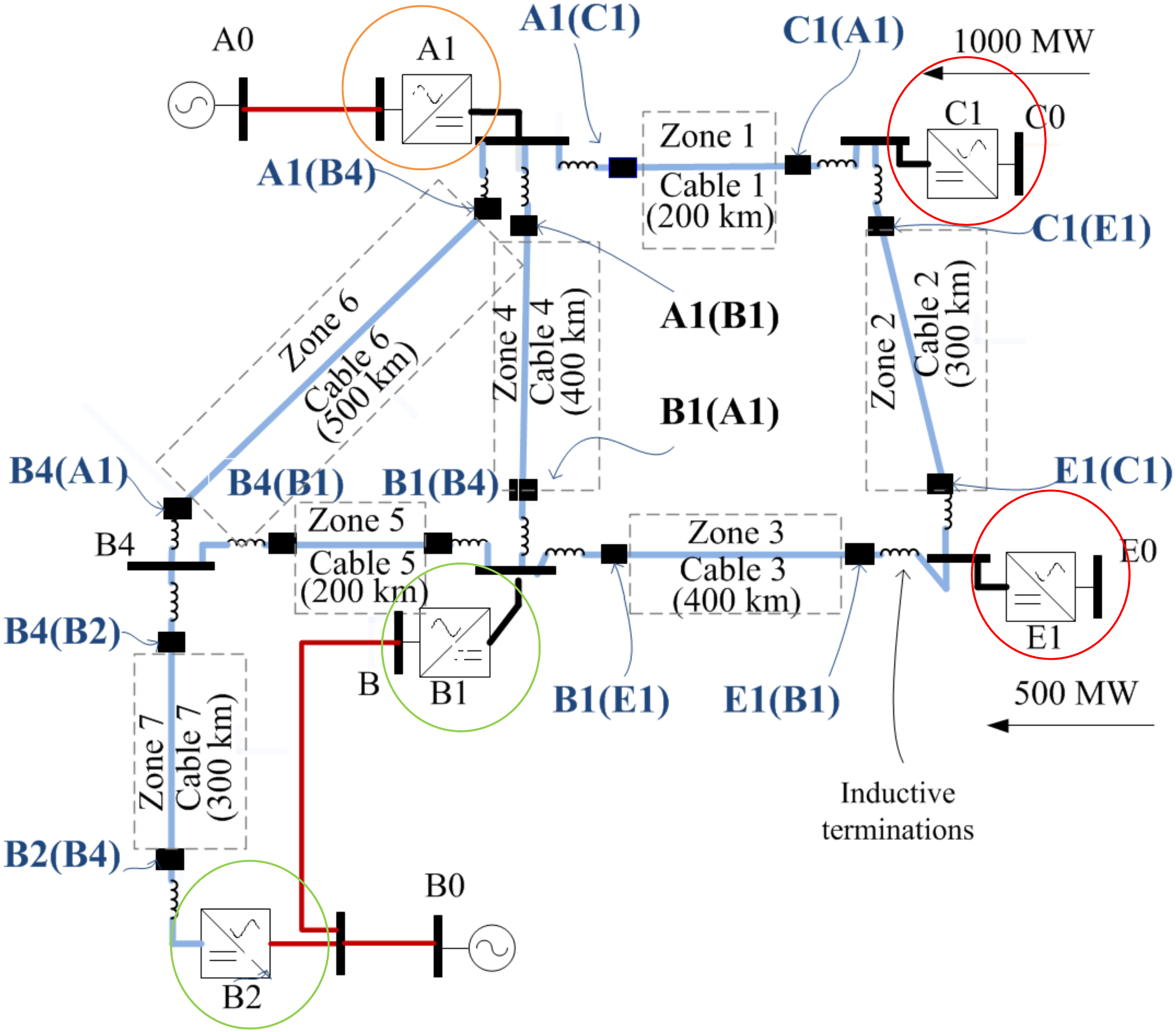
The proposed method has been designed based on the following assumptions:

- Only single-ended measurements are available, i.e. **the communications at cable level are considered unavailable**.
- dc currents are measured at relatively **high sampling frequency,** i.e. 200 kHz.
- **Inductive terminations**, which are near each protection relay, are considered.

Reference system

Simplified version of CIGRE B4 DC Grid Test System has been proposed, and it consist of:

- ❑ Ring Configuration
- ❑ Five terminal (MMC)
- ❑ Two controls DC voltage
- ❑ Two island mode
- ❑ One is exporting power



Numerical simulations

Different cases have been considered to show the selectivity of the proposed method

Case study	Protection zone	Location	Inductive terminal (mH)	Fault resistanc e (Ohms)
1	Zone 1	1 km from A1	-	0.0001
2	Zone 3	1 km from E1	-	0.0001
3	Zone 5	1 km from B4	-	0.0001
4	Zone 7	1 km from B4	-	0.0001
5	Zone 1		0.1-10	0.0001
6	Zone 1		10	1-100

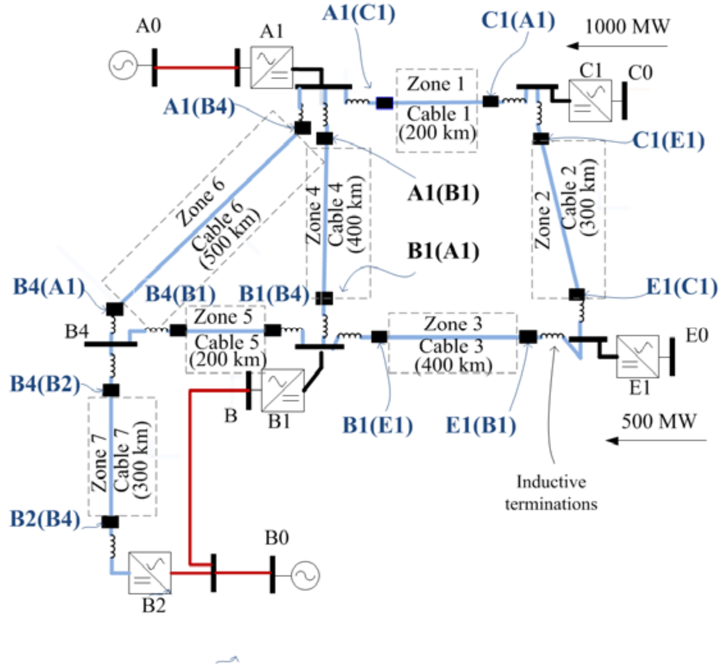
To Illustrate selectivity problem (cases 1–4)

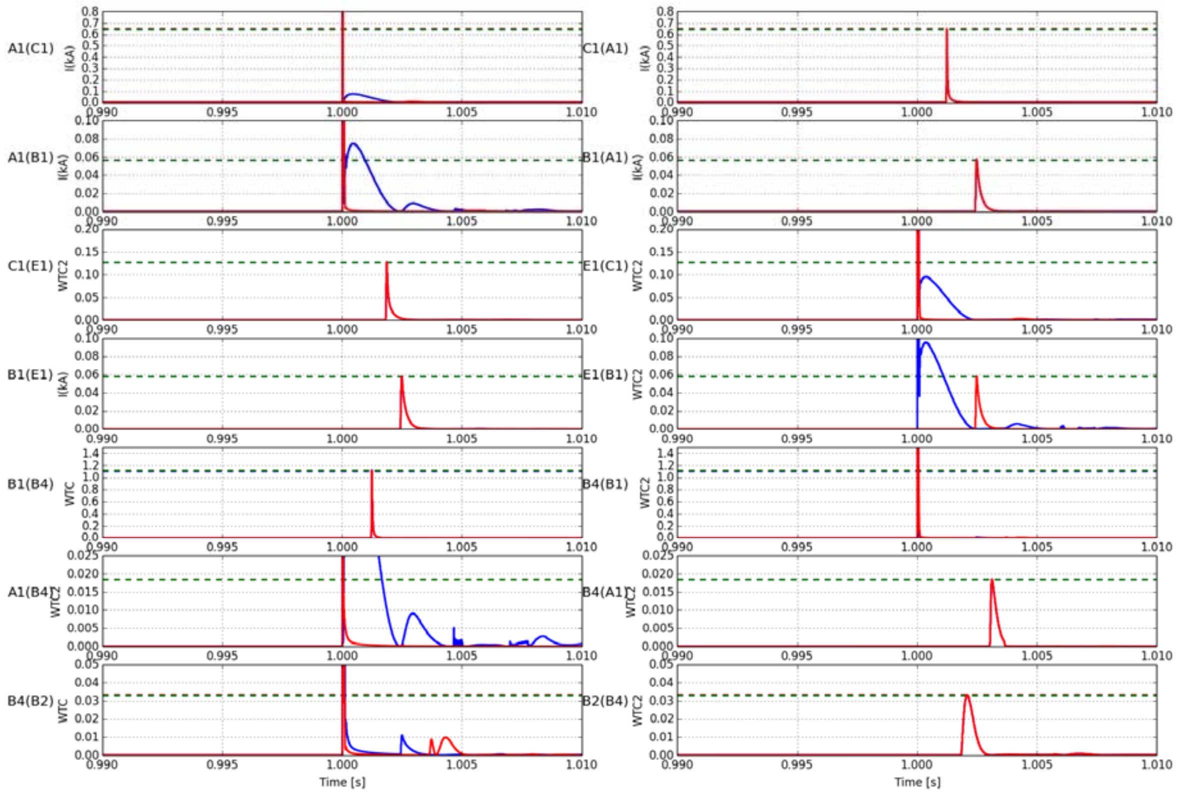
Effect of the inductive terminations (case 5)

High impedance faults (case 6)

Selectivity on fault location in meshed HVDC

A fault ocurrs at cable 1 near convert A1, there are not current limiters





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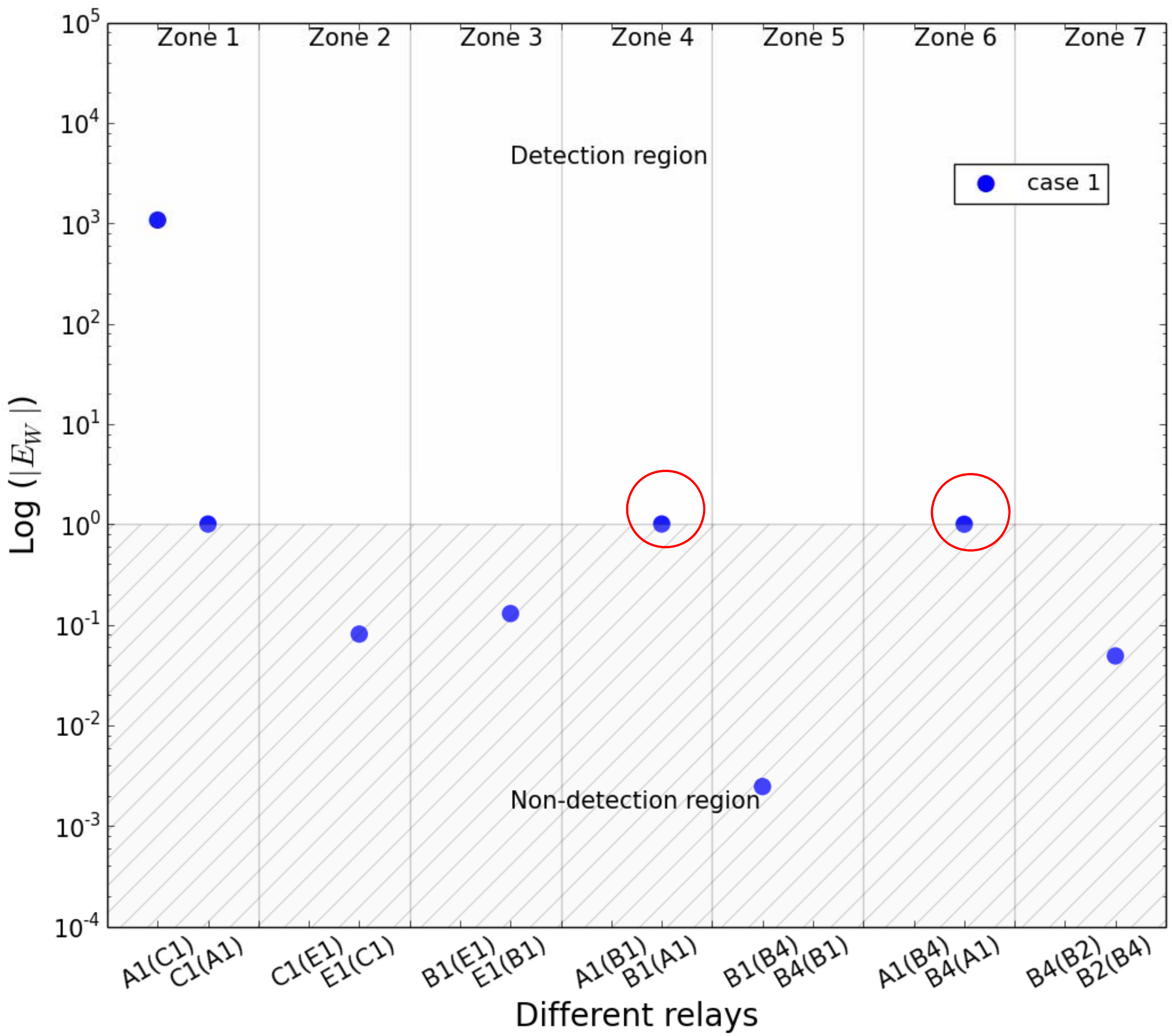
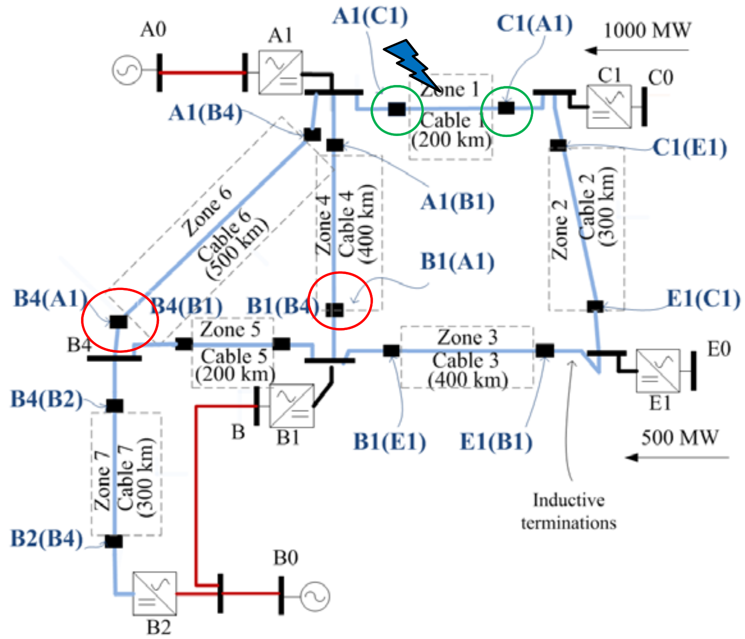
Selectivity on fault location in meshed HVDC

Case 1-4:

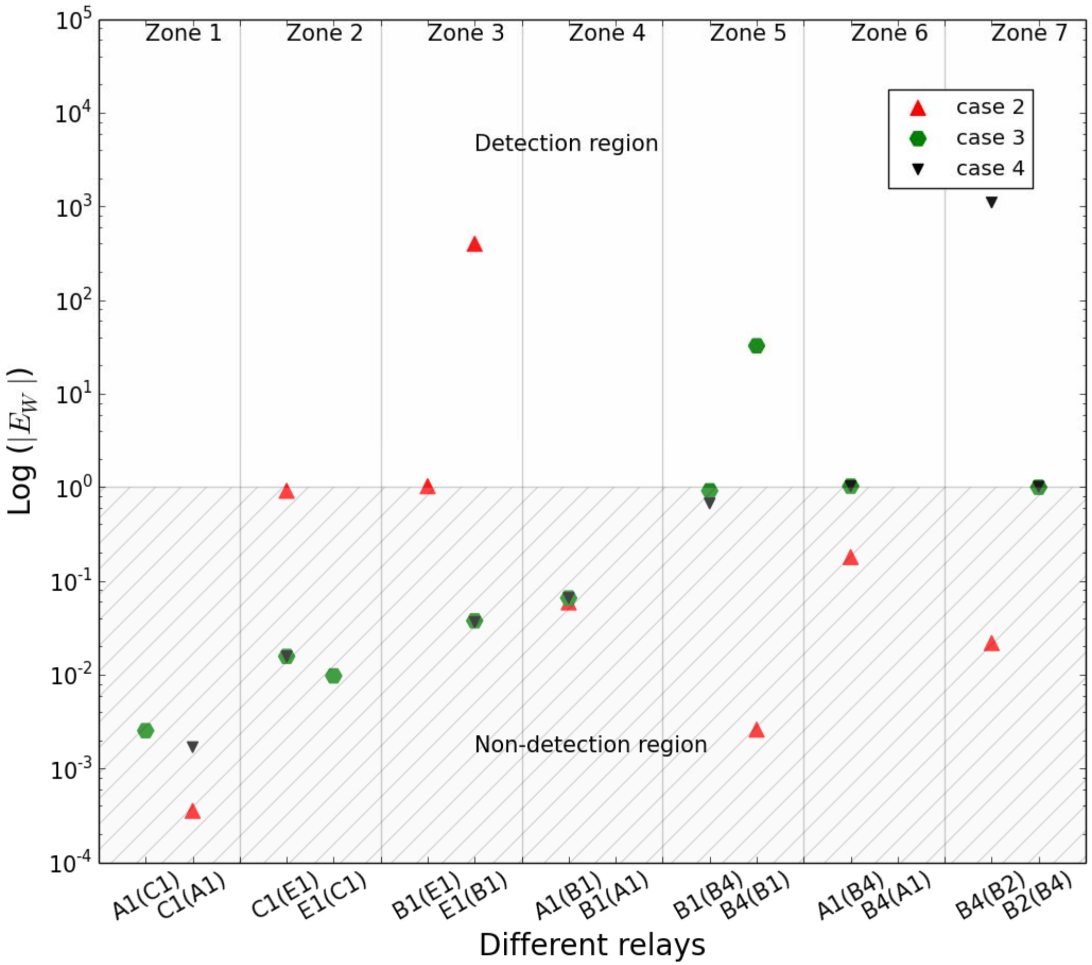


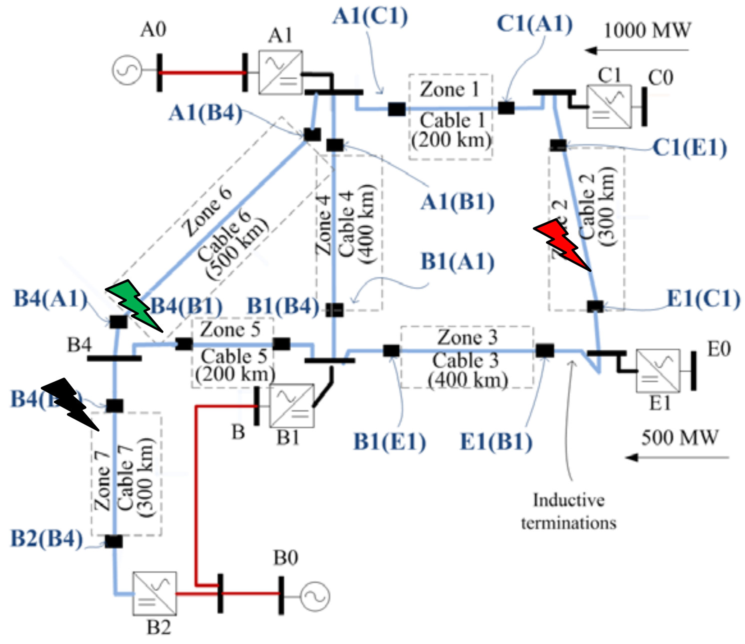


- Fault occurs at protection zone 1. Close convert A
- No inductive terminations
- The protection region where the fault occurs is identified
- There are two false detections

Selectivity on fault location in meshed HVDC

Case 1-4:

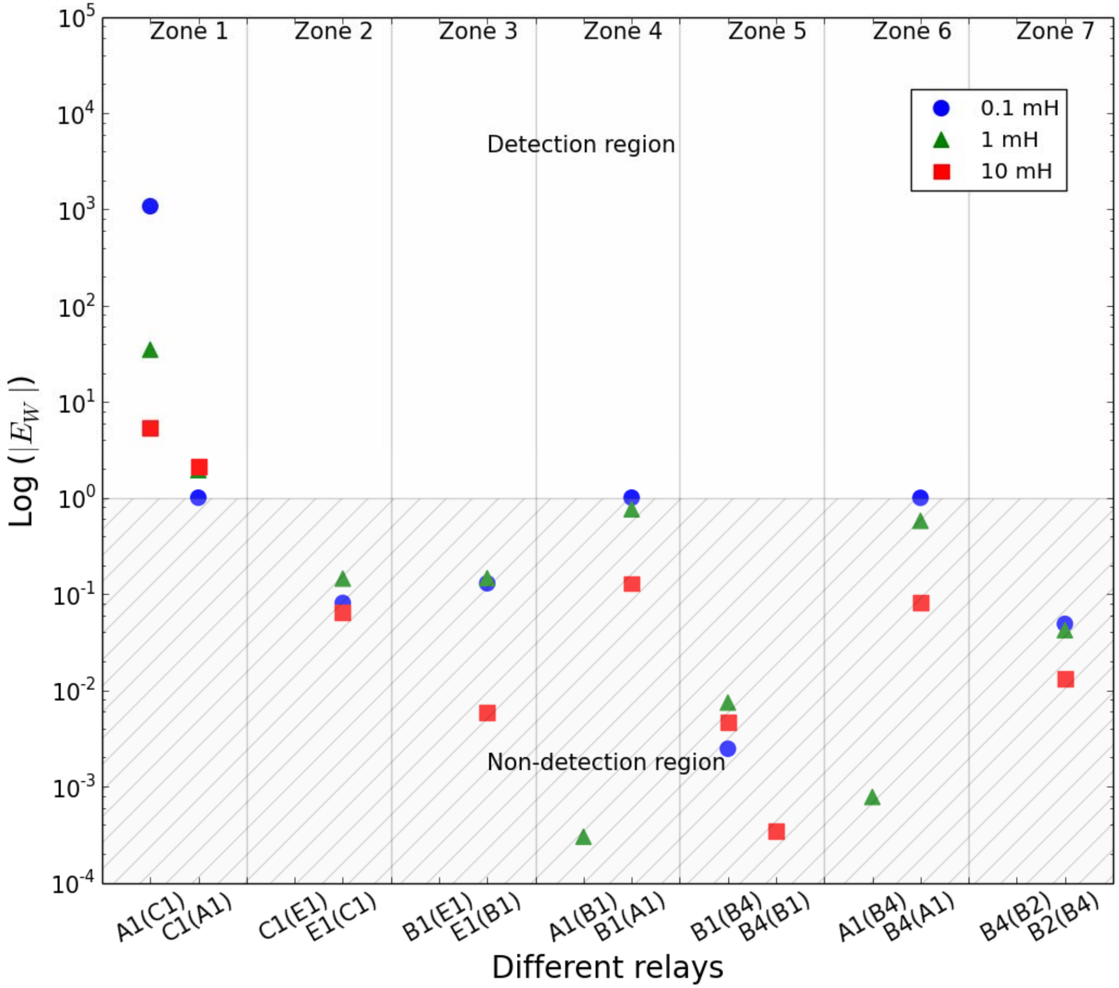


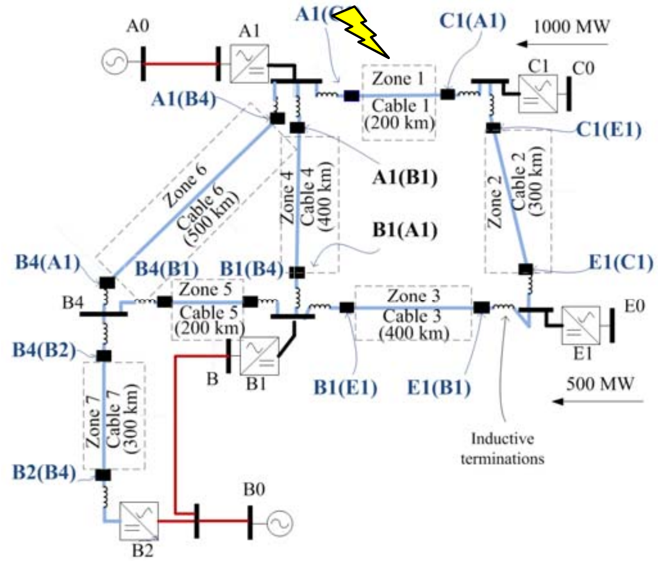


- The same occurs with the rest of the cases.
- There are false detections

Selectivity on fault location in meshed HVDC

Case 5:





- Fault occurs at protection zone 1. Close convert A
- Three inductive terminations are investigated
- All cases the protection zone is identified
- Small inductors have little influence in the selectivity
- The false detections disappear with a proper value of the inductor

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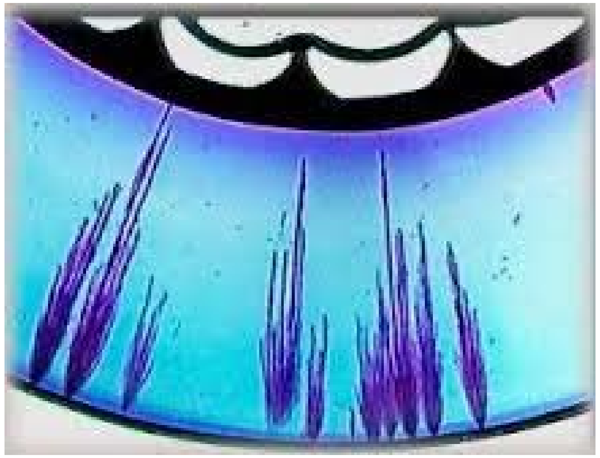
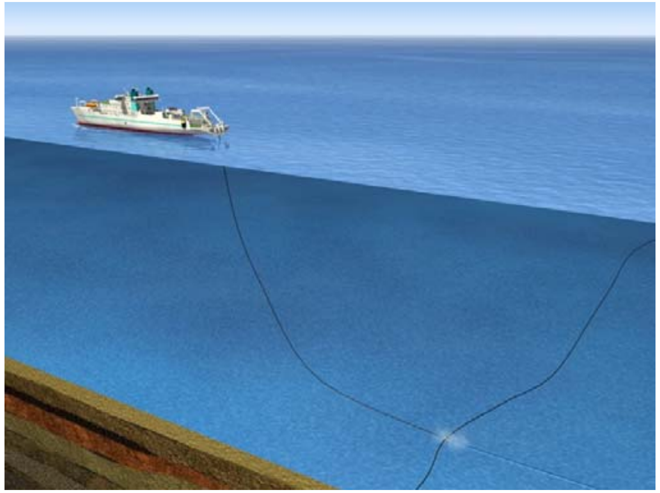
High impedance faults

- High impedance faults (HIF) usually happens as a result of insulation failure or unintentional contact with any external non-conductive element.
- When cables are subjected to environment with high level of humidity (>65%), the insulation layer may begin to break down this is called water treeing.
- Second, HIF can occur because of a cable cut, or breakdown.

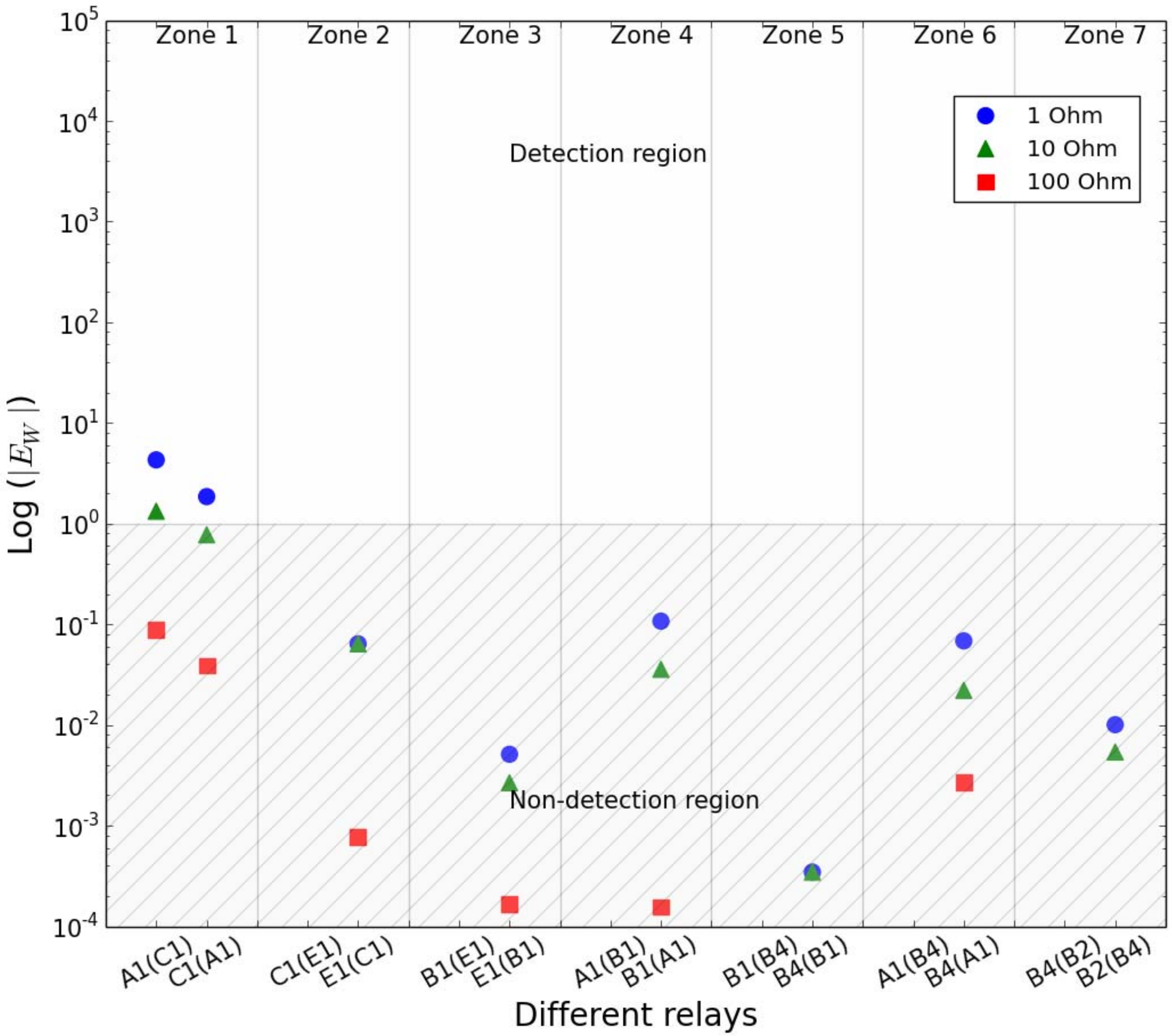


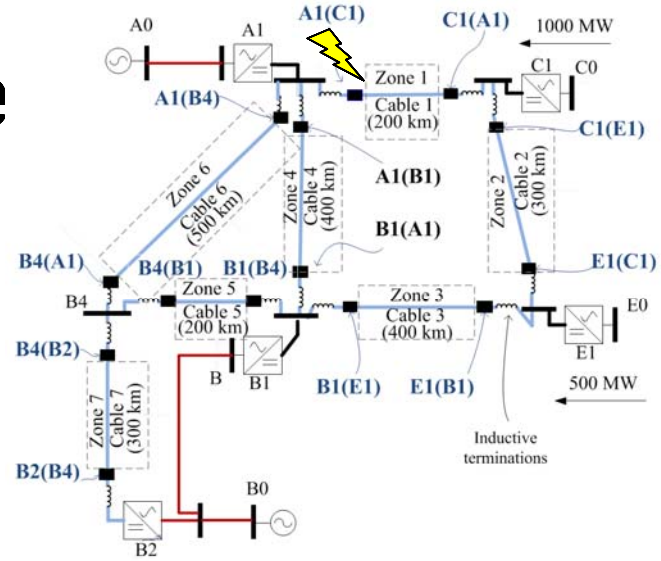


LONG-LIFE XLPE INSULATED POWER CABLE Hampton et al Jicable'07

Selectivity on fault location in meshed HVDC-High impedance

Case 6:





- Fault occurs at protection zone 1. Close convert A
- Three resistance values are investigated
- The scheme work well with the smallest value
- It doesn't work with high impedance values

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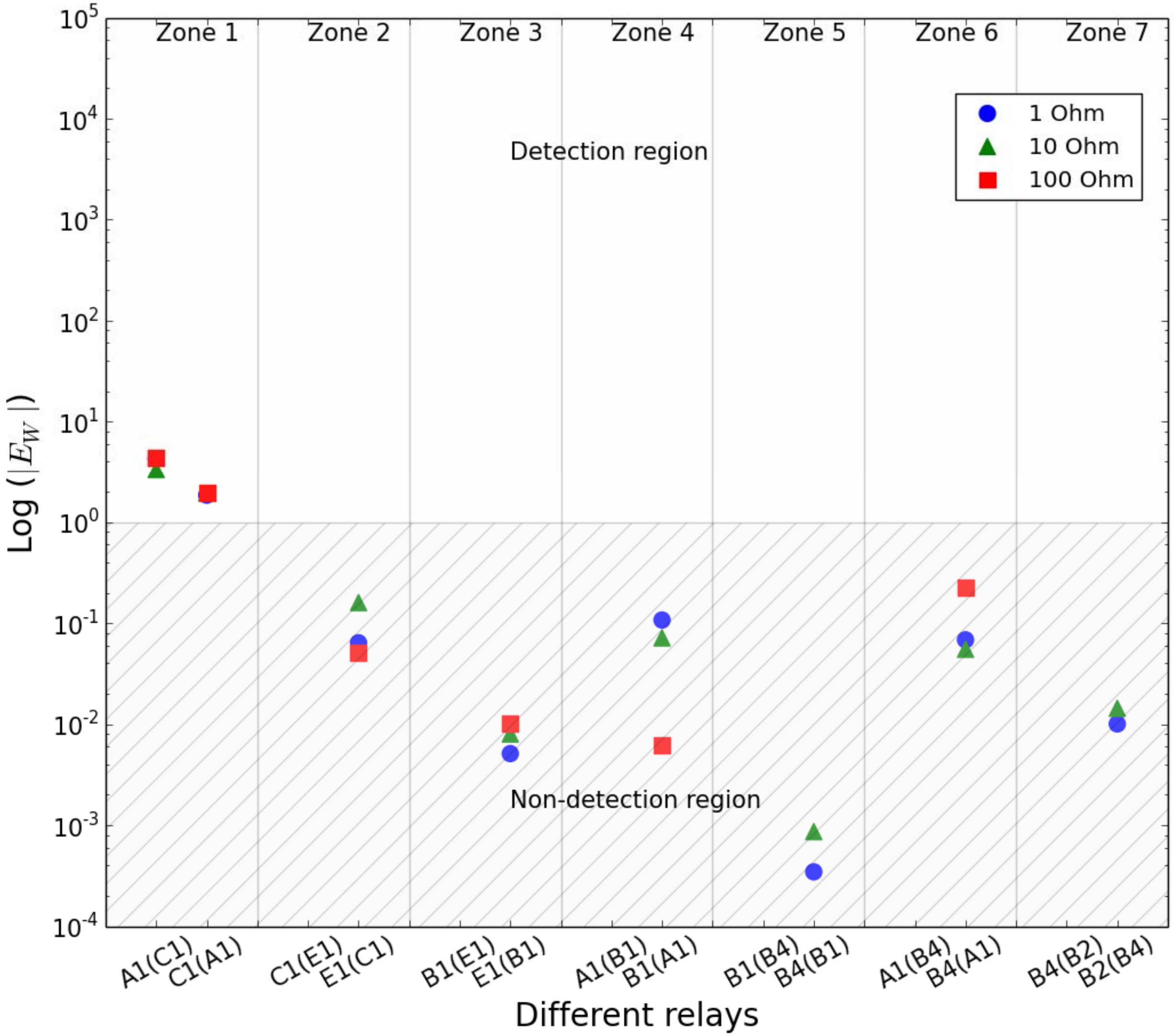
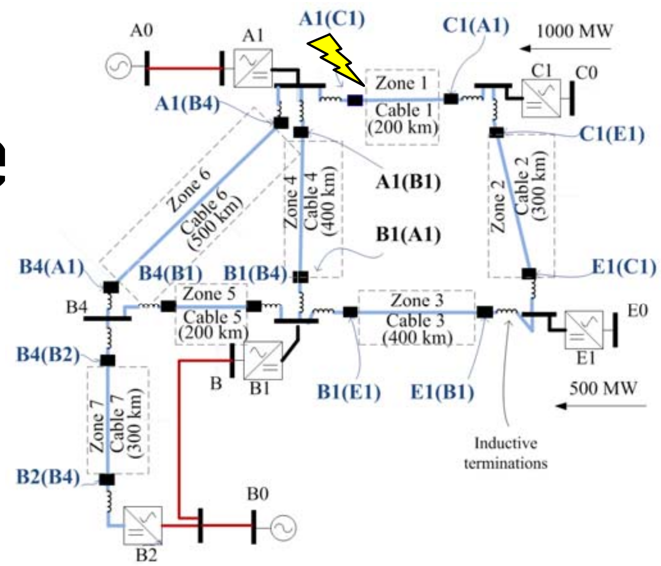
Selectivity on fault location in meshed HVDC-High impedance

Case 6:





- Thresholds are recalculated
- Now the scheme is able to work properly

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Sensitivity on fault location in meshed HVDC configurations using wavelets

Sensitivity refers to the ability of the method to discriminate between normal operation or external disturbance, and DC faults

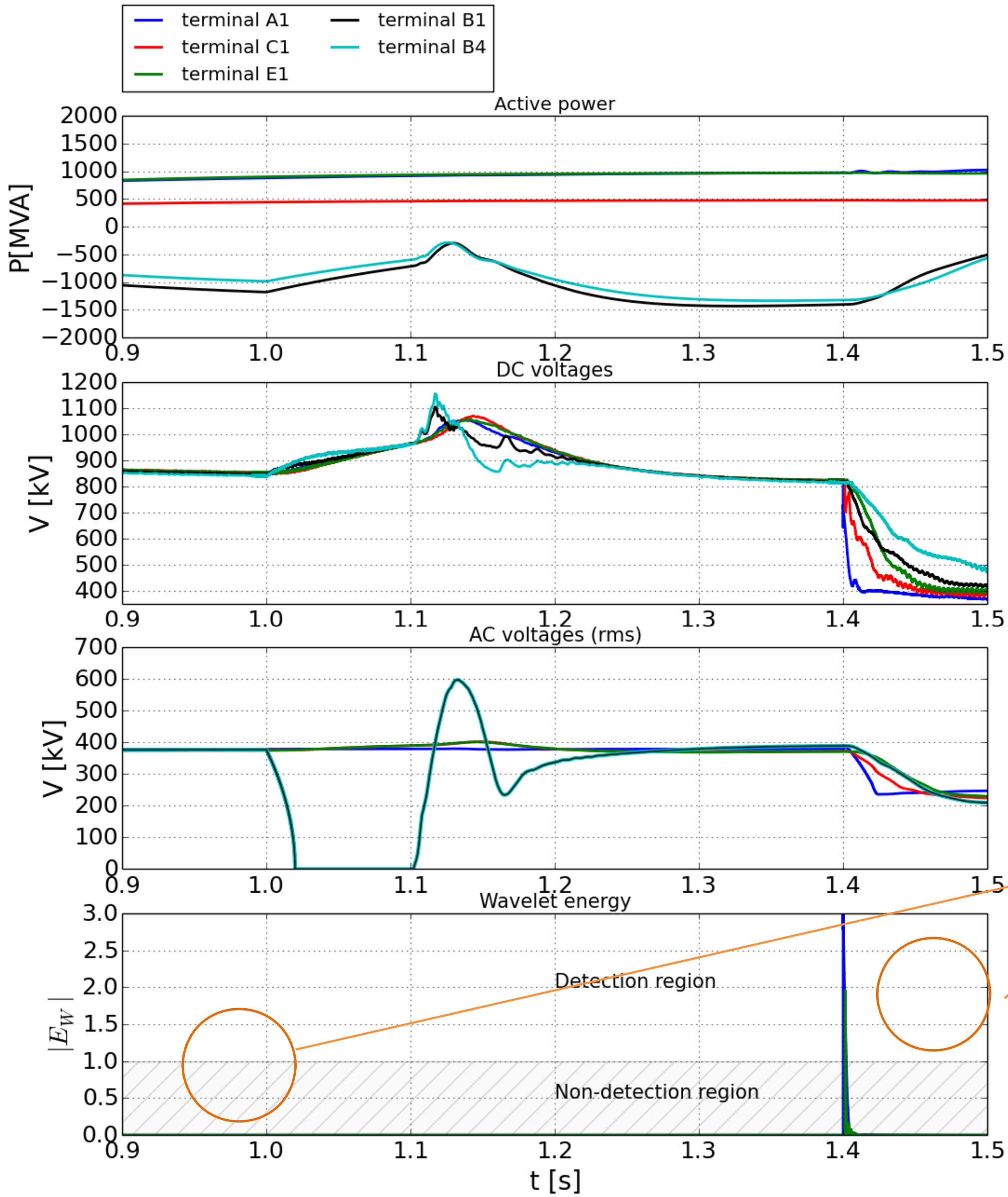
Three cases has been tested for sensitivity:

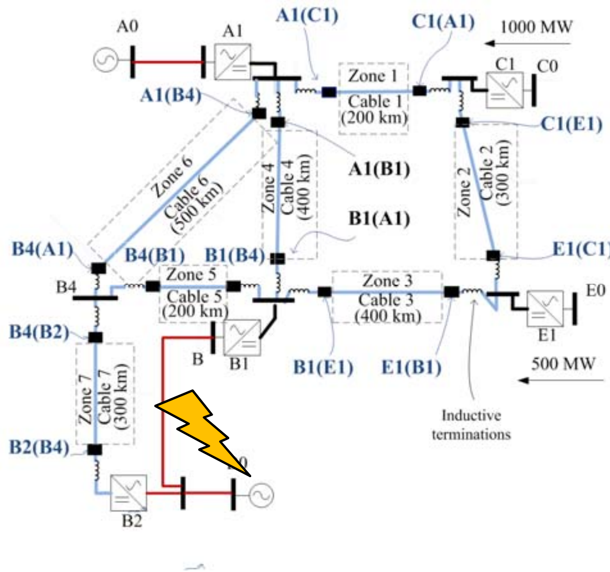
- Energization transients
- Disconnection transients
- AC faults

Sensitivity during AC fault transient

Figure shows the time response of the system during:

- First, a three-phase-to-ground AC fault occurs at 1.1 s.
- Second, Pole-to-ground dc fault at 1.7 s.





Wavelet energy when ac fault occurs is negligible compared with dc fault

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Concluding remarks

- This paper presented a non-unit detection algorithm which is based on the comparison of the magnitude of the high frequency transients in the travelling waves of the dc current
- The scheme needs the incorporation of inductive terminals in order to provide high selectivity.
- High impedance faults were investigated where thresholds need to be recalculated.
- The sensitivity was tested under different scenarios including AC faults and load changes. The proposed method is able to discriminate between dc fault and external disturbances.

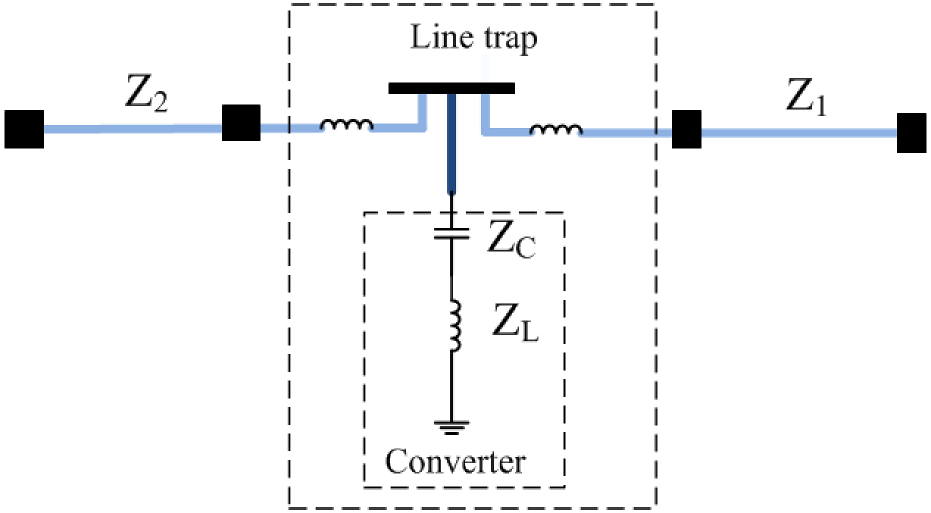
Thanks for you attention

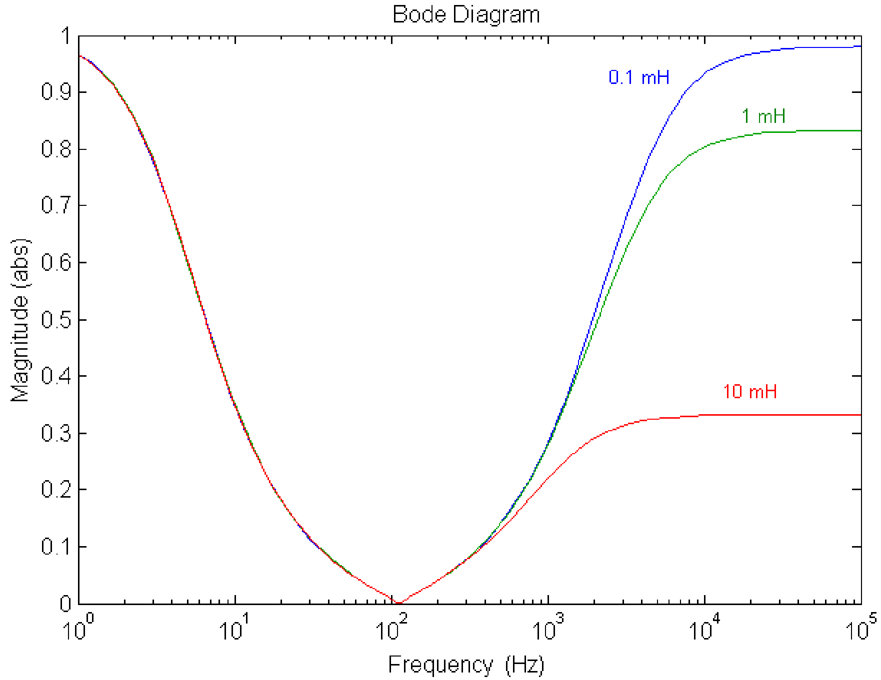
Setting of threshold

1. Choose a cable: **cable 1**
2. Determine the maximum possible wavelet energy for the breaker should trip (with the protection zone): **To apply a fault at the end of the cable.**
3. Determine the minimum possible wavelet energy for the breaker should not trip (outside the protection zone): **To apply a fault in the adjacent relay**
4. Check the selectivity to external disturbances **Check if the wavelet energy is not greater when an external disturbance occurs.**
5. Repeat to all cables

Introduction

The scheme is based on the comparison of magnitudes of the high frequency transient. Considering that current transducer (CT) has better characteristic of transducing high frequency signals compared with voltage transducers.





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