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Field data evaluation for lines connected with renewable sources: Way forward

Presented By

Aarthi V, R&D Engineer, Hitachi Energy

CONTEXT

- Introduction
- Relevance
- Challenges of Over Current relay for IBR connected systems
- Challenges of Distance relay for IBR connected systems
- Challenges of Line differential relay for IBR connected systems
- Key Takeaways/Recommendations
- References

INTRODUCTION

Renewable energy capacity growth

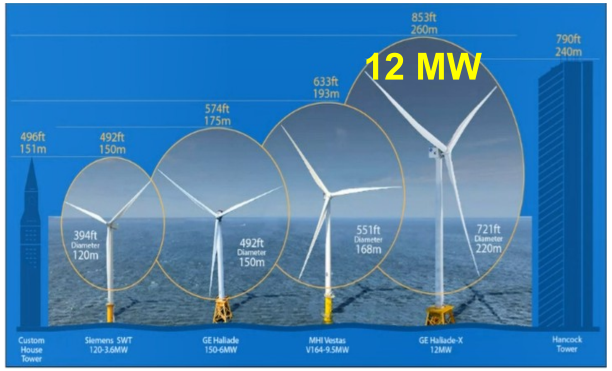
- **Energy Demand by 2050 :** Industry double **(2X),** Buildings **(50%)** and transportation **(30X)**
- We need 4X today's energy generation and 3X transmission lines
- **Renewables growth: I**ncrease by **75-90%** (today average RE capacity is **20%**) replacing fossil-fuels by 2050 as per IEA, IRENA
- India to increase renewable installed capacity to **500 GW** by 2030
- Paradigm shift driven by **climate goals**, **energy security**, **economy** and **technological advancements**

Accelerated offshore technology growth

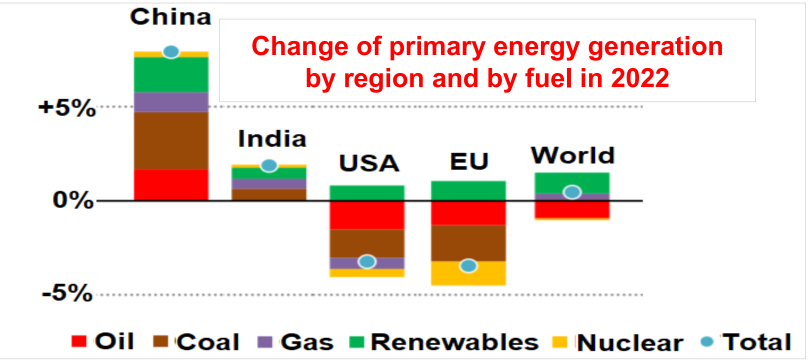
- Onshore wind capacity growth expected to remain stable in the coming years - offshore systems set to further accelerate
- Europe's share of installed offshore capacity to decline from 50% in 2021 to 30% in 2027- China, USA to become large markets by 2027*
- Floating wind farms – to unblock vast potential of ocean areas which are too deep for fixed turbines – Japan, Korea, Portugal, France and west coast of USA

Floating solar park

Floating wind park



Technology Advancements in offshore wind



Global scenarios

Renewables to transform and lead the global power mix by 2030, a poses key challenges to power system protection and monitoring

RELEVANCE

Our focus for today

Challenges with existing Protection methods for renewable sources must be addressed

Reliable and secure Power System Protection required for renewable connected systems

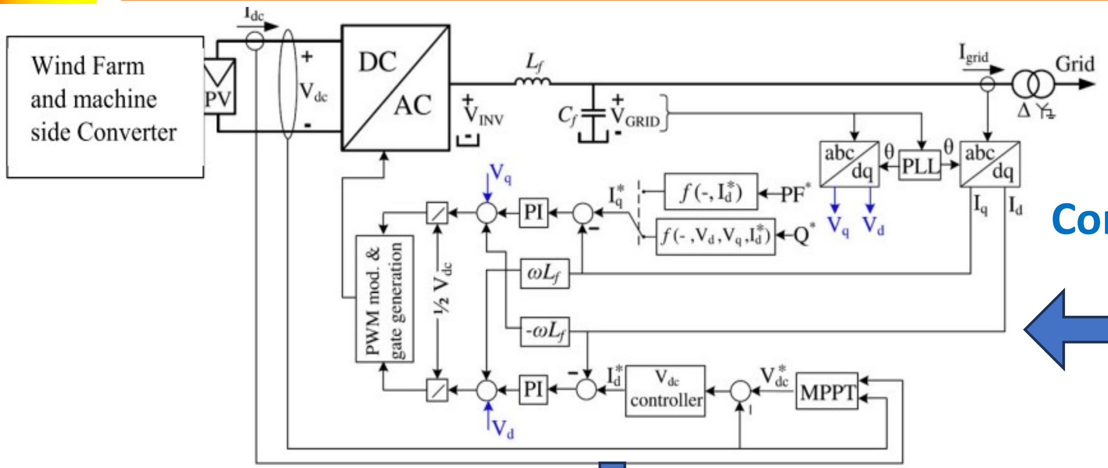
Large Integration of renewables

To overcome climate change and global warming

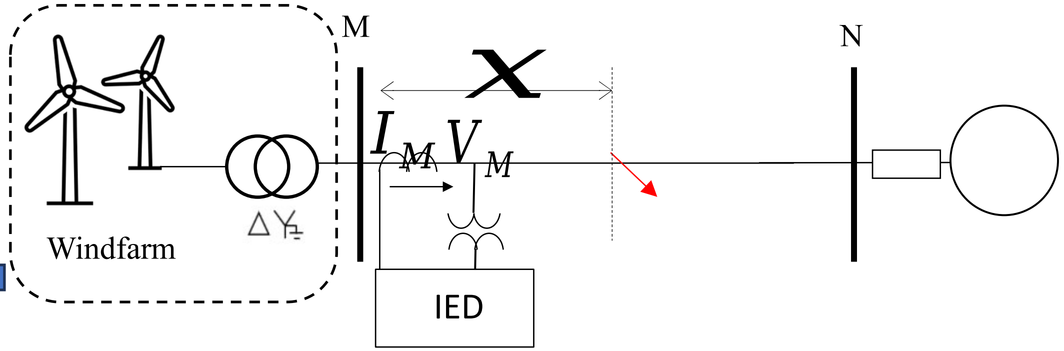
Reduced carbon footprints

India @ 100 in 2047: Vision for Indian Power System

Challenges of OC relay for IBR connected systems



Converter control scheme

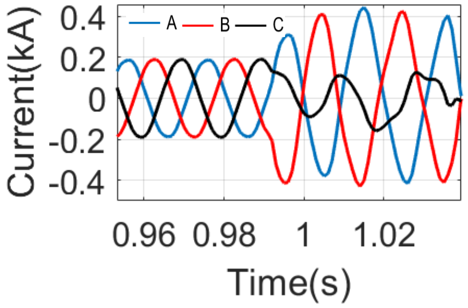


SLD of transmission line connected to renewable source

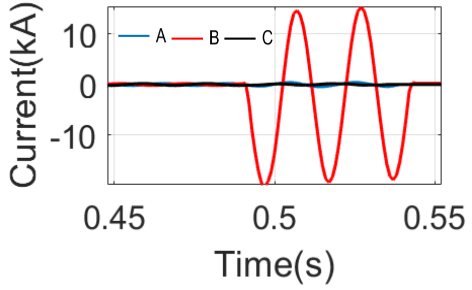
Fault current modulated

Current waveforms for field data (obtained from a windfarm connected system in western part of India)

Windfarm end



Grid end

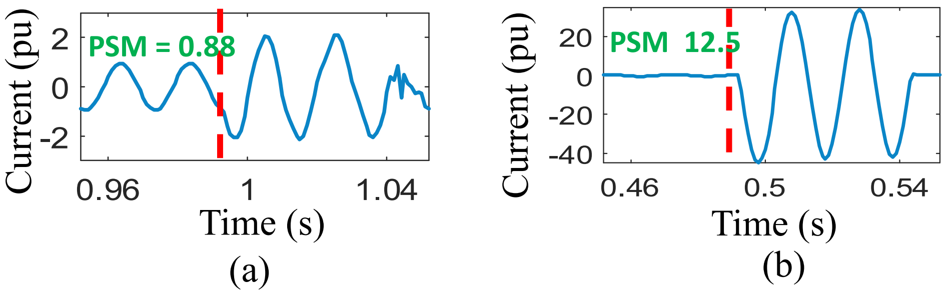


Fault current limited due to converter controls (Windfarm side)

Maloperation of Overcurrent relay

Waveforms of Phase B current in (pu) for field data

Windfarm end **Grid end**



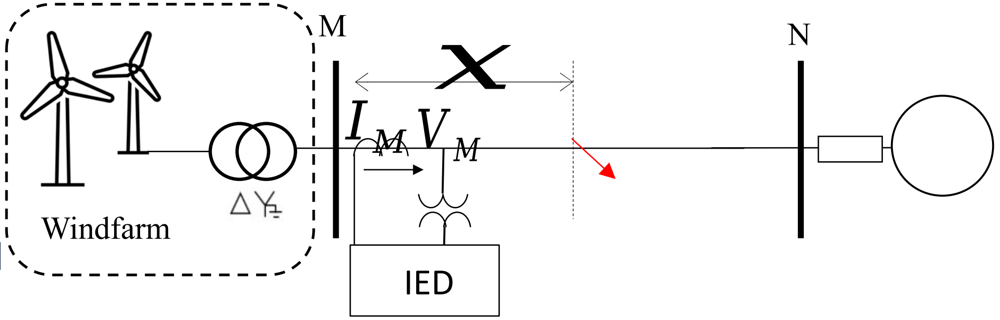
Phase B current for field case for relay at a) IBR b) Grid end.

Fault current does not exceed the plug setting

Challenges of Distance relay for IBR-connected systems

- Abnormal angle shifts in voltage and current
- Varying source impedance (IBR = weak source)
- Reactive current generation criteria changes with grid codes
- Balanced current even during asymmetrical faults.

Converter control scheme



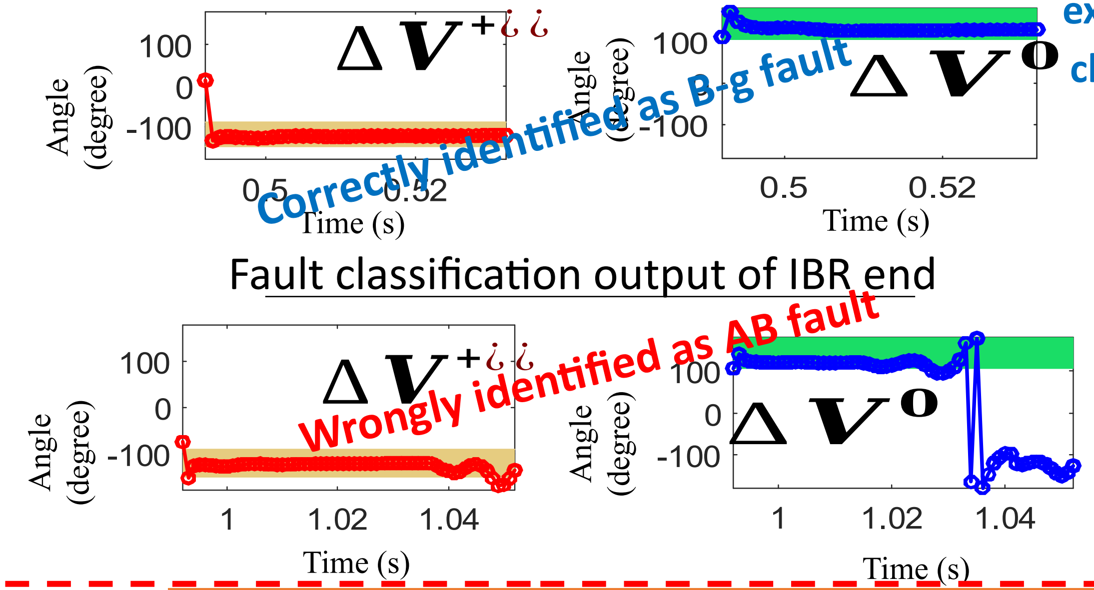
SLD of transmission line connected to renewable source

Maloperation of existing Fault classification

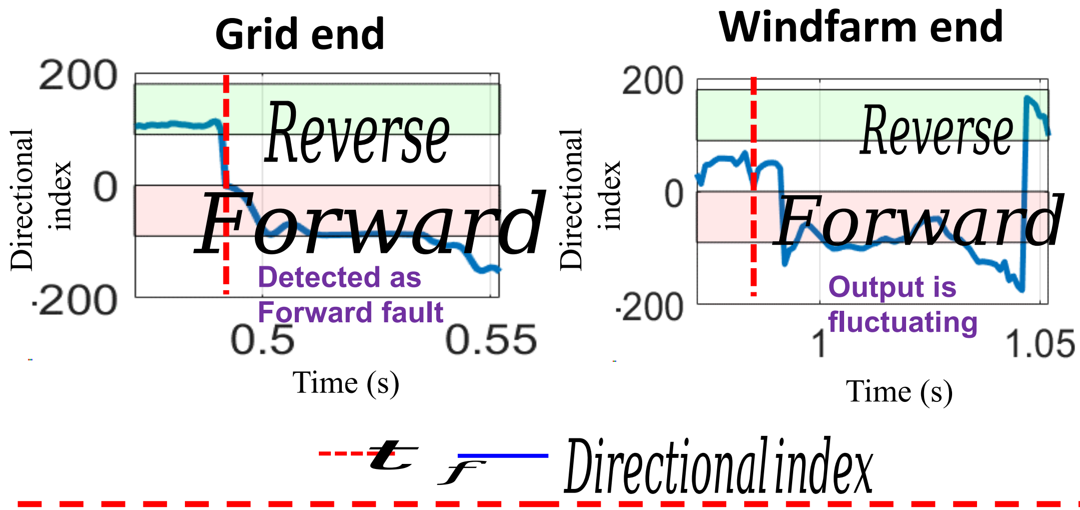
Maloperation of existing Fault direction methods

Fault classification output of Grid end

Fault classification output of IBR end



Fault direction output for field data



Challenges of Distance relay for IBR-connected systems

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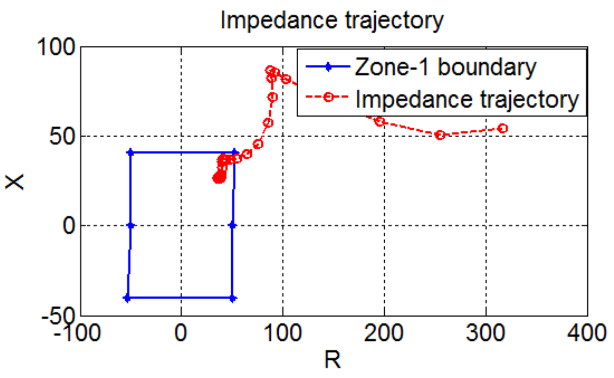
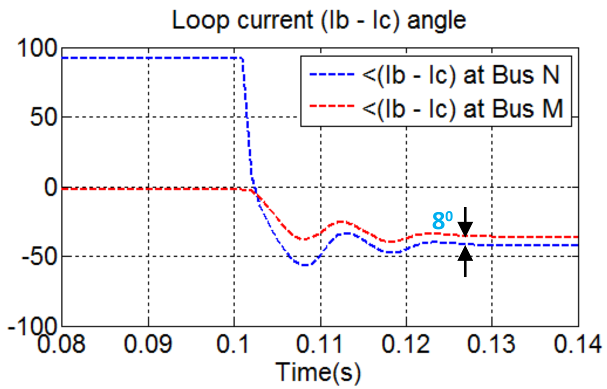
Z_F = 2.14 +**30.46i**

Calculations

Conventional Generation





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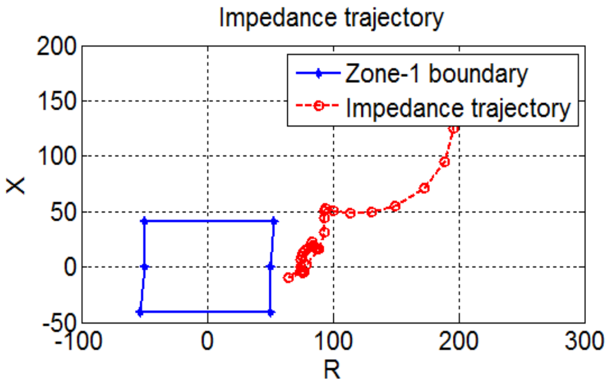
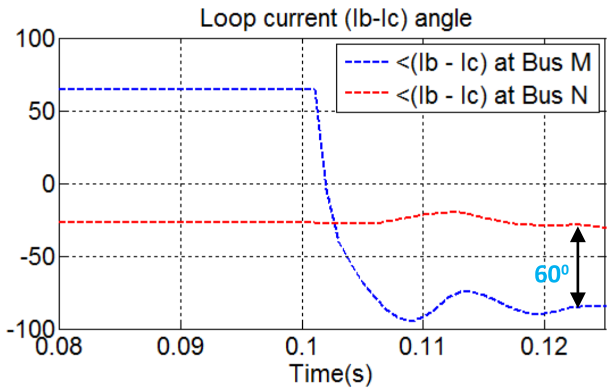
= 39.27 +**41.16i**

Wind type IV Generation





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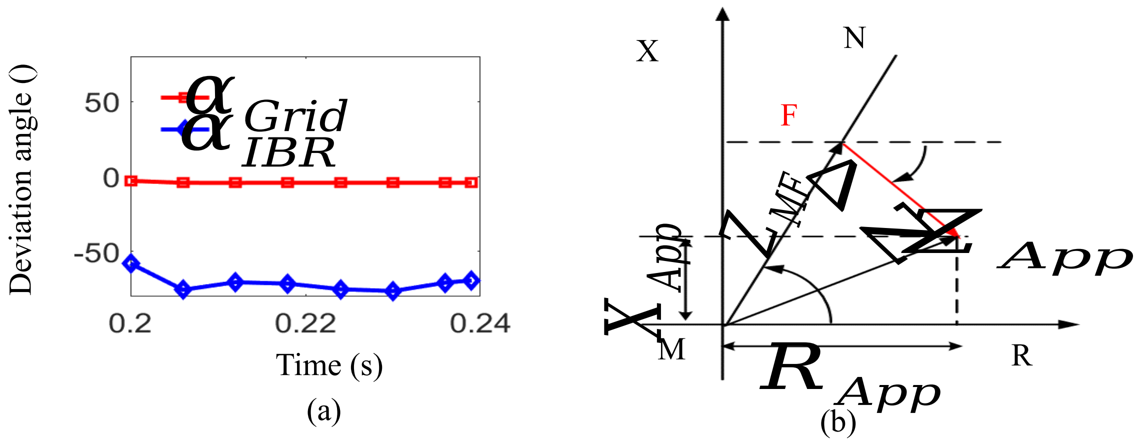
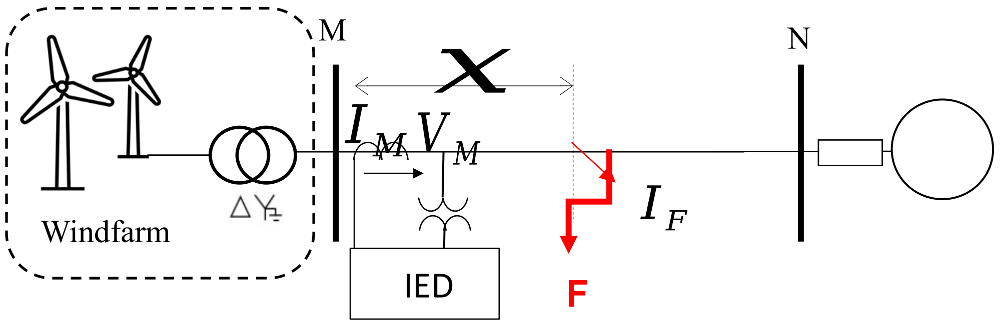
= (67.32 - **8.22i**)

- Change in reactance reach = **-39**Ω
- Trajectory moves to the fourth quadrant

Challenges of Distance relay for IBR-connected systems

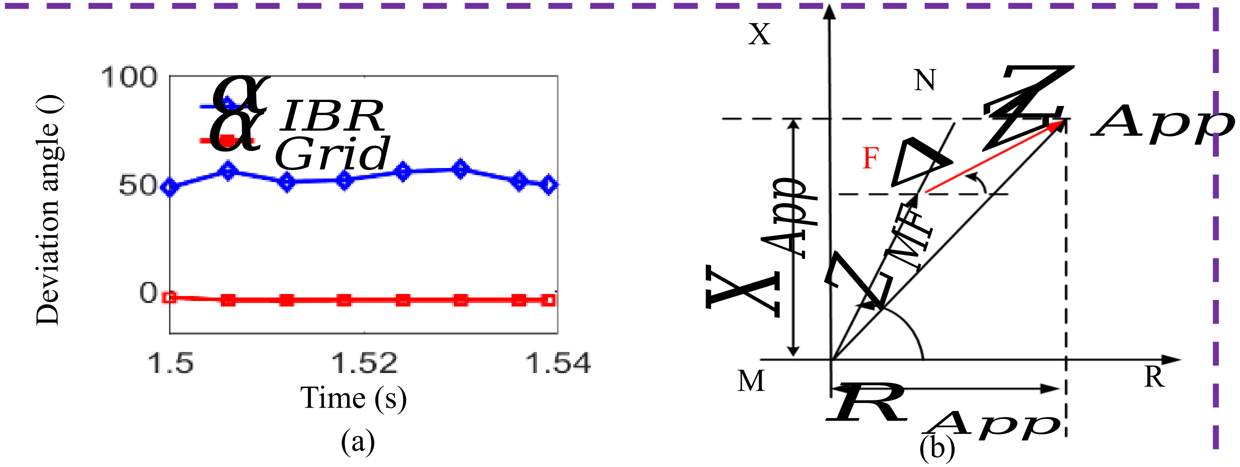


Grid code - 1 (a) angle difference between the fault current and current measured by fault locator (IED) and (b) impedance of the IED at Bus M.



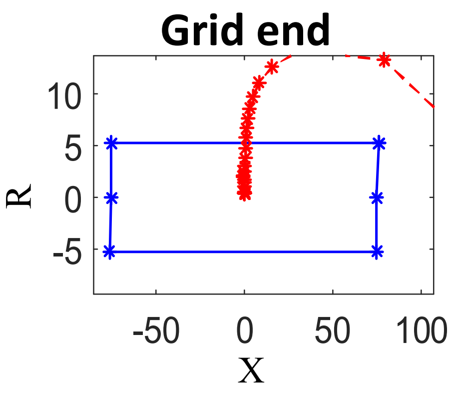
SLD of transmission line connected to renewable source

$$Z_{app} = Z_F + R_F I_F \qquad \alpha = \frac{I_F}{I_M}$$



Grid code - 2 (a) angle difference between the fault current and current measured by fault locator (IED) and (b) impedance of the IED at Bus M.

Plot of Impedance trajectory for field data

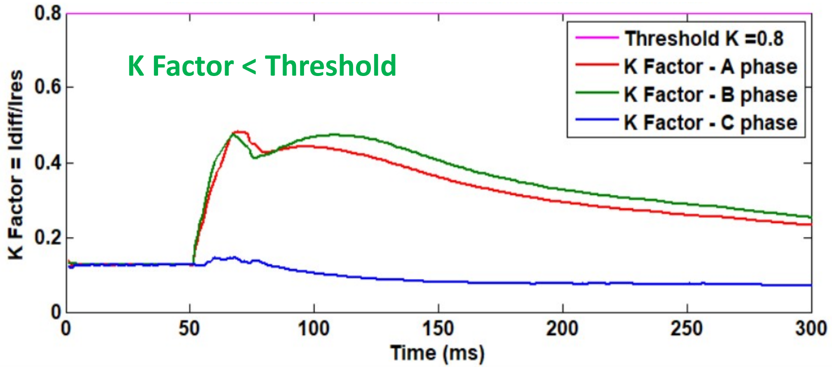


Correctly identified as Zone -1 fault **Does not settle in any zone**

Challenges of Differential relay for IBR-connected systems

Linear characteristics

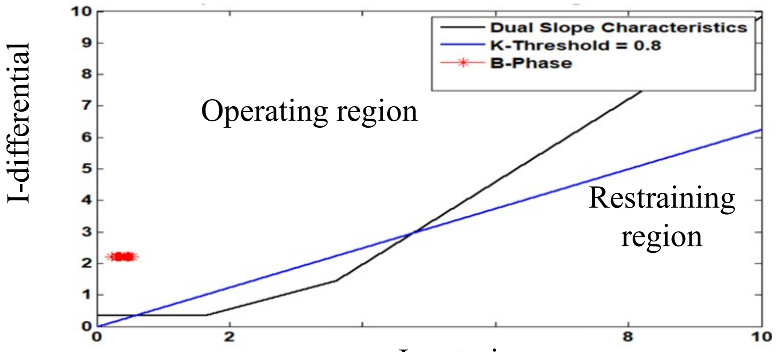
Plot of K Factor for AB fault at 1.5 km



Differential relay will operate with a low sensitivity or even malfunction

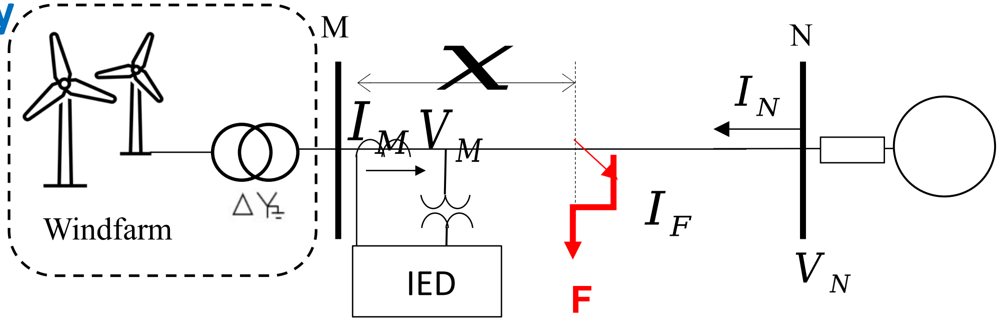
Dual Slope characteristics

Plot of K Factor for field data (B-g fault)



Dual Slope characteristics no impacted by converter controls

Non-homogeneity factor



SLD of transmission line connected to renewable source

$$K = \frac{I_{Op}}{I_{Res}} \qquad I_{op} = I_{diff} = |I_M + I_N|$$

$$I_{res} = \frac{|I_M - I_N|}{2}$$

¿ $I_{op} \geq K \cdot I_{res}$ ¿ ¿

It was observed that the line differential relay is reliable for IBR connected systems with incorporation of both linear and dual slope characteristics

KEY TAKEAWAYS / RECOMMENDATIONS

- Due to the presence of converter controls in IBR-connected systems,
  - Fault current is modulated
    - Poses challenge to Overcurrent protection
  - The angles of voltage and currents are impacted
    - Poses challenge to Fault classification and Direction
  - Introduces non-homogeneity in the system
    - Poses challenge to distance protection
- The line differential protection seems to be promising when incorporating both linear and dual slop characteristics
- Hence it is recommended to use line differential protection for IBR connected systems

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