Advanced Distribution Protection for High Penetration of Distributed Energy Resources (DER)

Yaswanth Nag Velaga[1], Kumaraguru Prabakar[1], Akanksha Singh[1], PK. Sen[2], Benjamin Kroposki[1]
[1]National Renewable Energy Laboratory (NREL), [2]Colorado School of Mines

Objective:

- Increased DER penetration poses a major challenge to the system protection
- Legacy overcurrent schemes are not adequate
- Schemes that are independent to changing fault currents and can adapt to different configurations is required
- Time-domain based protection is proposed to enhance the reliability of the system with diverse DER penetration

Challenges

High Pen PV/DER
- Low fault current
- Reverse power flow
- Bottleneck for high penetrations of PV
- Intermittent nature of DER resources
- Need adaptive settings

Resiliency
- High-impact, low-frequency events
- High impedance faults
- Damage prevention
- System recovery
- Survivability

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- For a transmission fault, distribution DER to participate in fault ride through to support bulk grid stability
- Need to identify the low voltage event in transmission

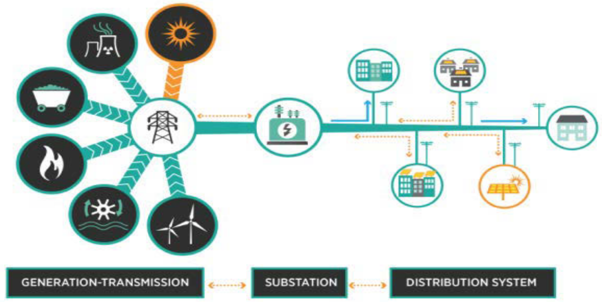
Grid Configurations
- Many utilities still perform the manual grid reconfiguration
- Islanded microgrids
- Unintentional islands

Current Research

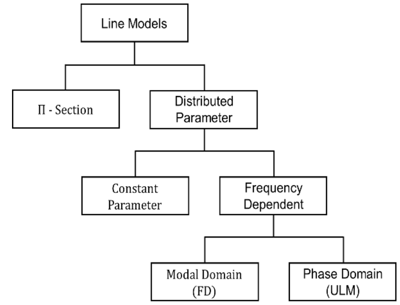
Adaptive Relaying | Machine Learning | Traveling Waves

- Adaptive relaying requires the communication to change between different setting groups
- Finding out all possible setting groups with different configurations is not possible
- Machine learning depends on available data to train and not suitable for different grid designs

Traveling Waves:
- Independent of phasor magnitudes
- Present for all type of faults
- EMTP simulations are required to analyze



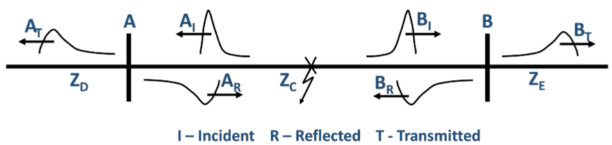
"Emerging Issues and Challenges with Integrating High Levels of Solar into the Electrical Generation and Transmission Systems," [Online]. Available: https://www.energy.gov/eere/solar/downloads/emerging-issues-and-challenges-integrating-high-levels-solar-electrical.



Universal Line Model (ULM) is widely used

Traveling Waves

- Traveling waves (TW) are electromagnetic transient phenomenon occurring for any disturbance in the circuit such as switching, fault, etc.
- Voltage and Current waves travel from fault location at close to speed of light for overhead lines and split into reflected and transmitted waves due to change in characteristic impedance at point of discontinuity



Voltage at A

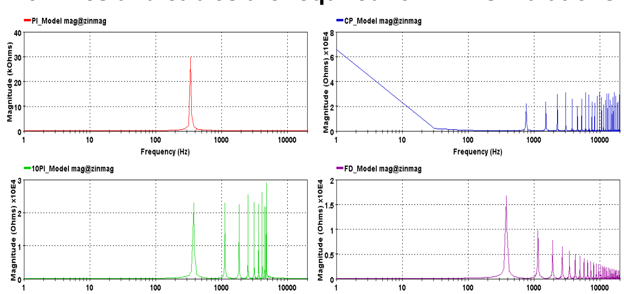
$$V_R = \frac{Z_D - Z_C}{Z_D + Z_C}, \quad V_T = \frac{2Z_D}{Z_D + Z_C}$$

Current at A

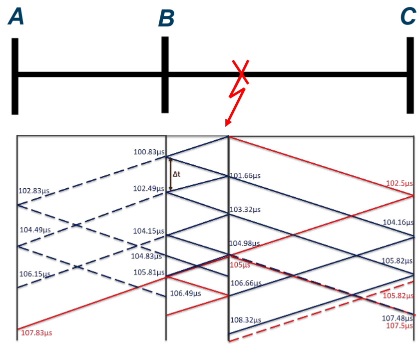
$$i_R = \frac{Z_C - Z_D}{Z_C + Z_D}, \quad i_T = \frac{2Z_C}{Z_C + Z_D}$$

Line Models

- Traveling waves are not captured by *Π* models
- CP model gives inaccurate results if the input frequency is not close to transient frequency
- Distributed parameter frequency dependent models for lines and cables are required for EMT simulations



Visualization: Bewley Lattice



- Devices located at the ends of line look for high frequency transients
- Depending on type of fault, different modes are present
- Bewley Lattice helps to track the arrival of transient time and fault location
- Bewley's Lattice has limited applications and not convenient for larger system

Conclusion:

- Numerous cases need to be analyzed for different faults
- Field validation is required to increase the reliability of time domain protection scheme
- Application to the distribution network is challenging

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