2024 Texas A&M Conference for Protective Relay Engineers

Protection of Wind Electric Plants

Prepared by Working Group C25,
Power System Relaying and Control (PSRC) Committee

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Outline

Summary Paper for the Report on
Protection of Wind Electric Plants

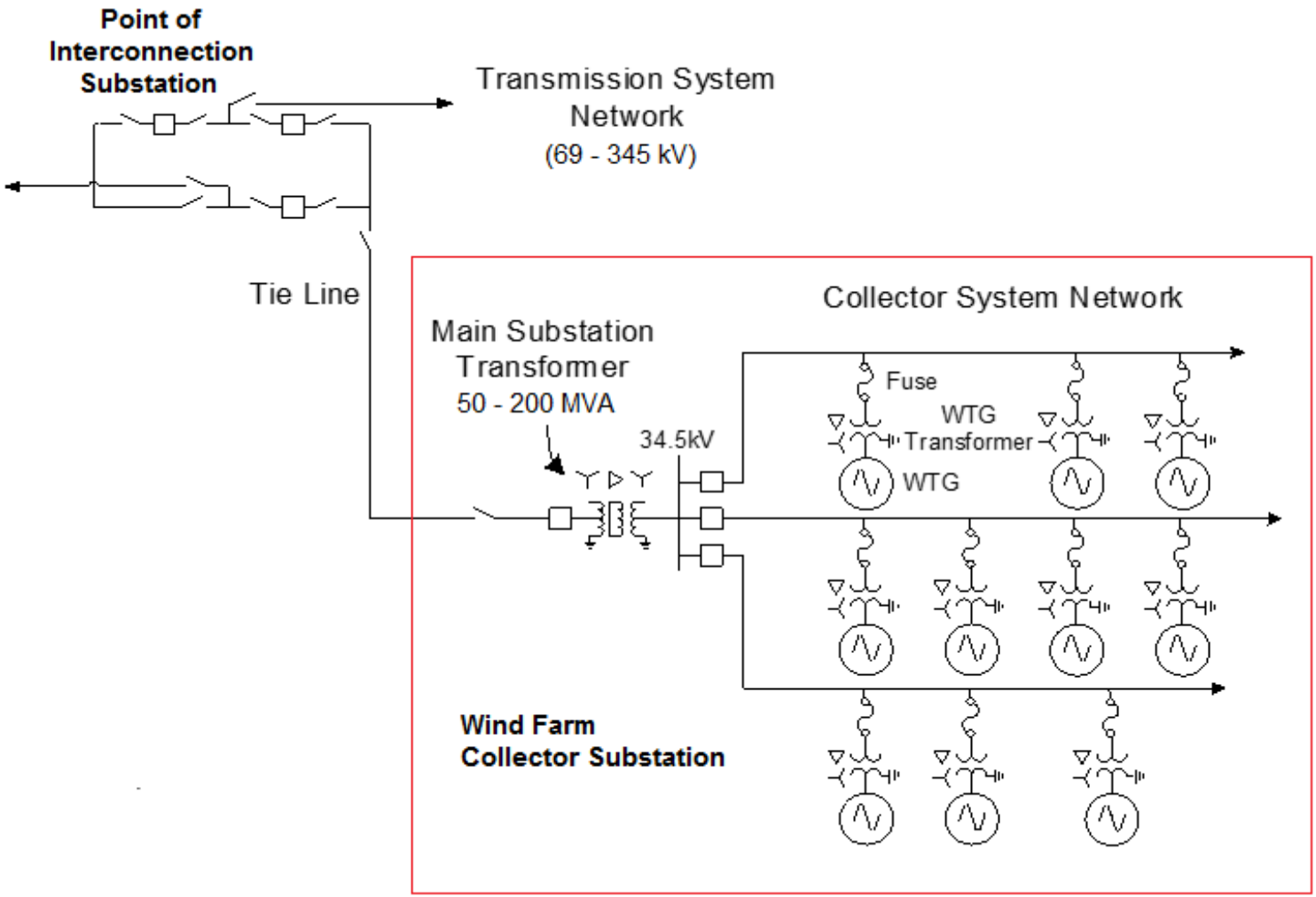
1. Introduction
2. Wind Electric Plant Substations vs Conventional Distribution Substations
3. Typical Protective Relay Schemes at Wind Electric Plants
4. Conclusion

Wind Electric Plant

Protection Overview

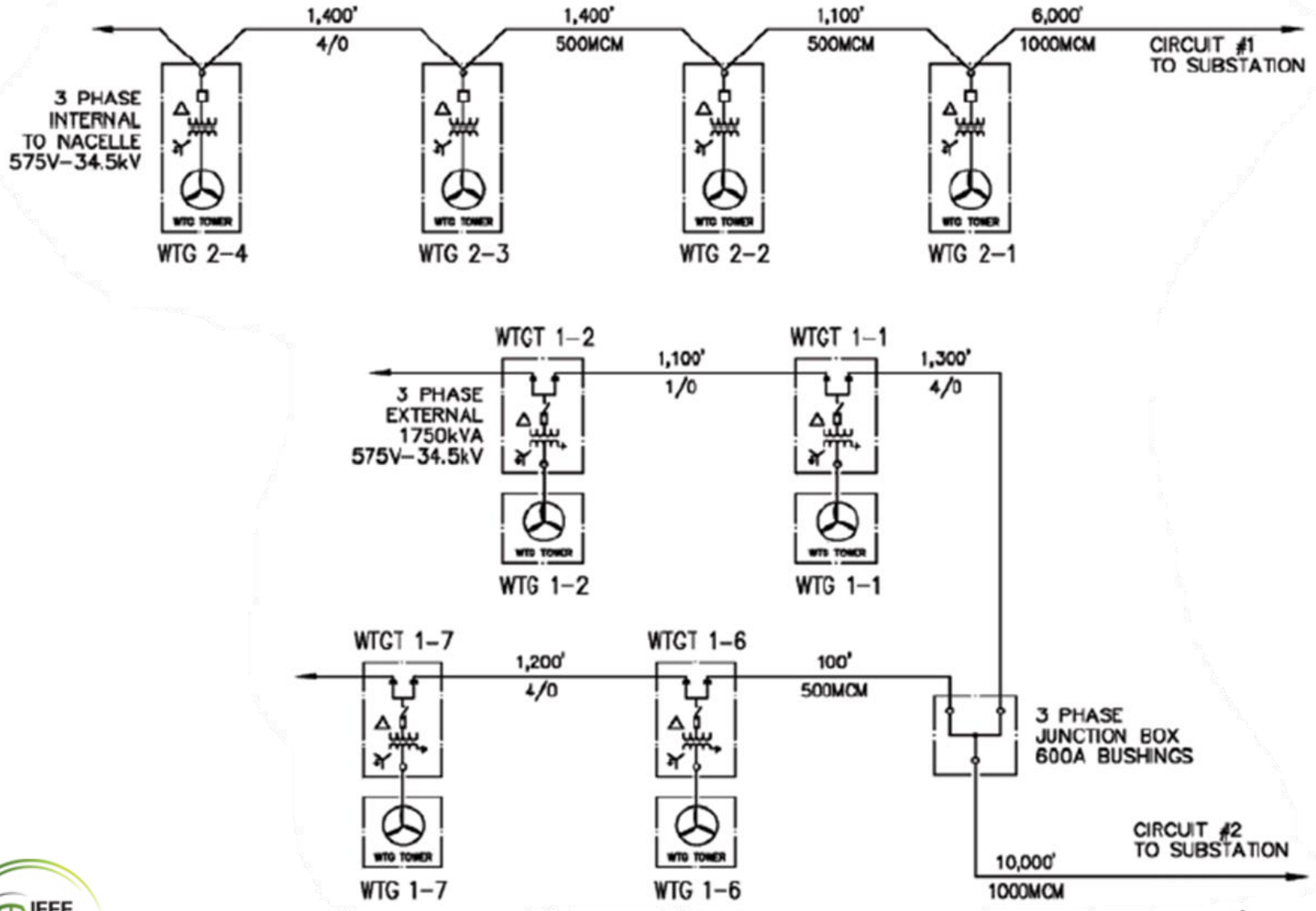
1. Collector Feeder Protection
2. Grounding Transformer Protection
3. Collector Substation Bus Protection
4. Main Power Transformer Protection
5. Capacitor / Harmonic Filter Protection
6. Transmission Tie Line Protection

One Line Diagram of a Typical Wind Electric Plant

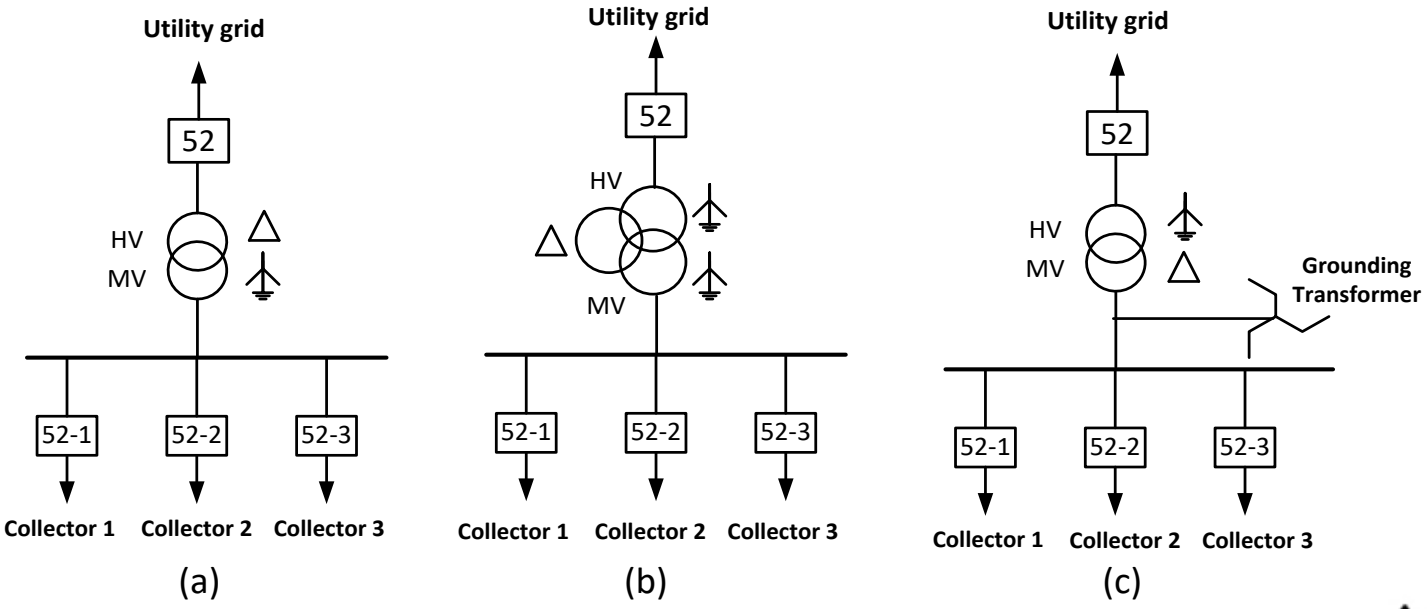


Typical Collector Feeder Cable Installation

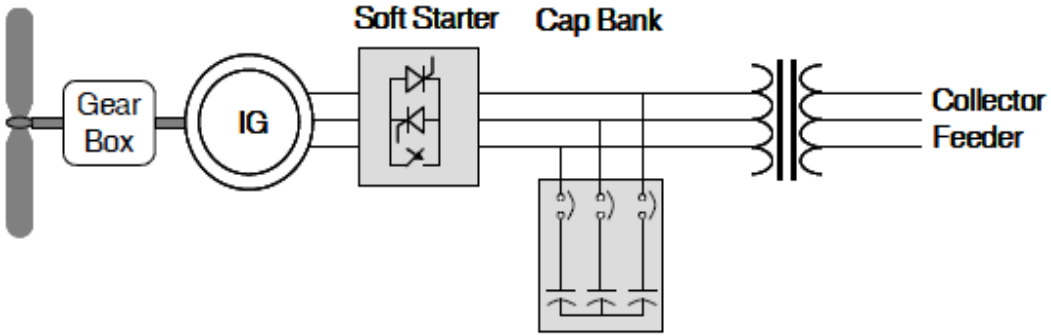
Typical Wind Electric Plant Collector Feeder Arrangement



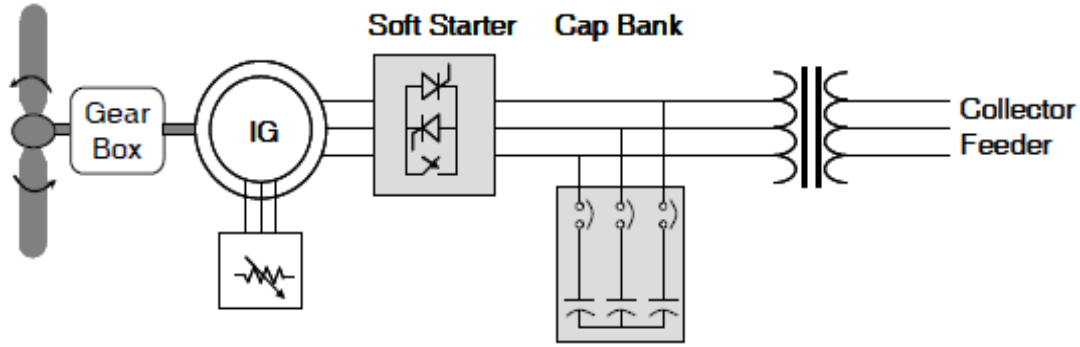
Typical Collector Substation



Typical Wind Turbine Generator Types

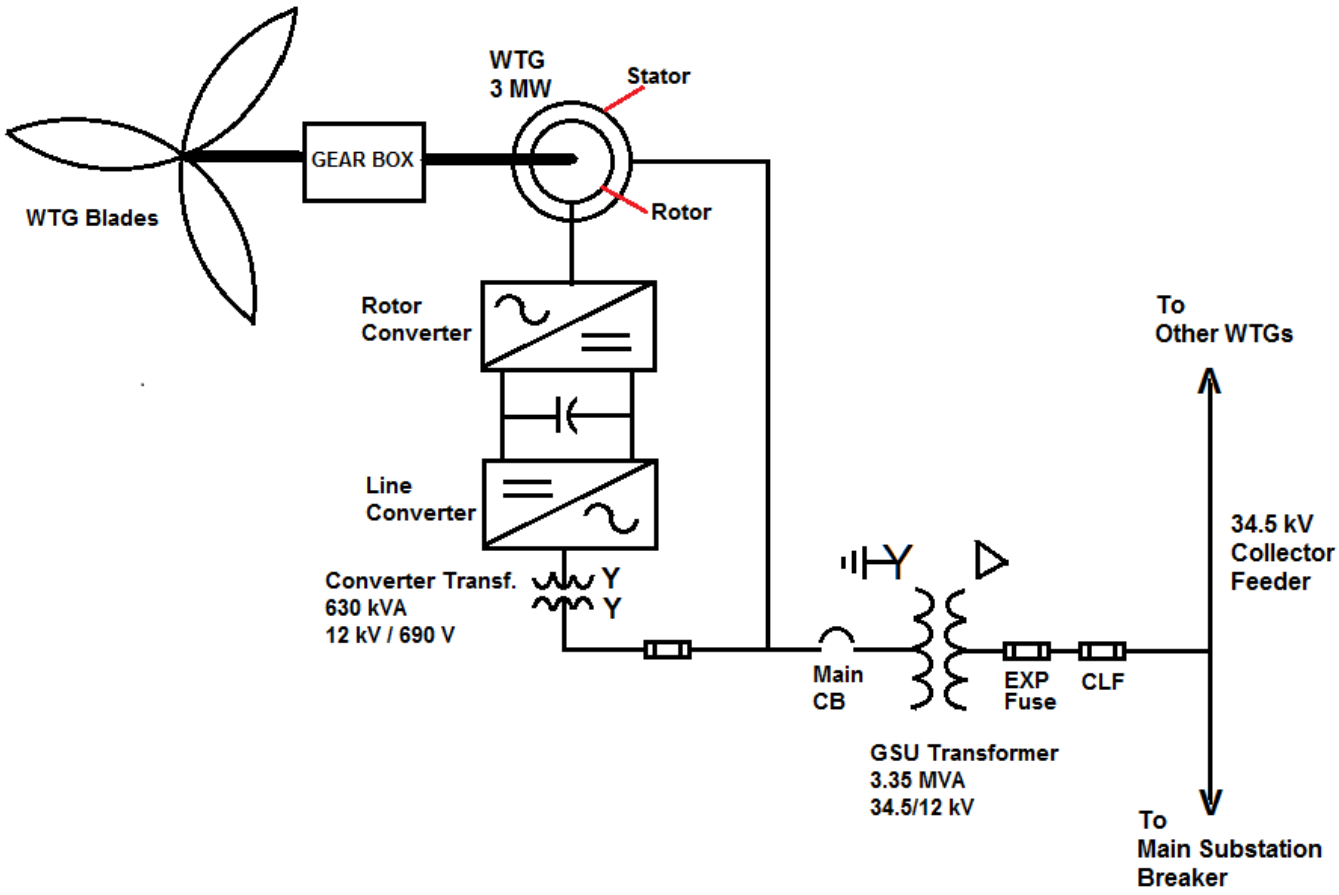


Type 1

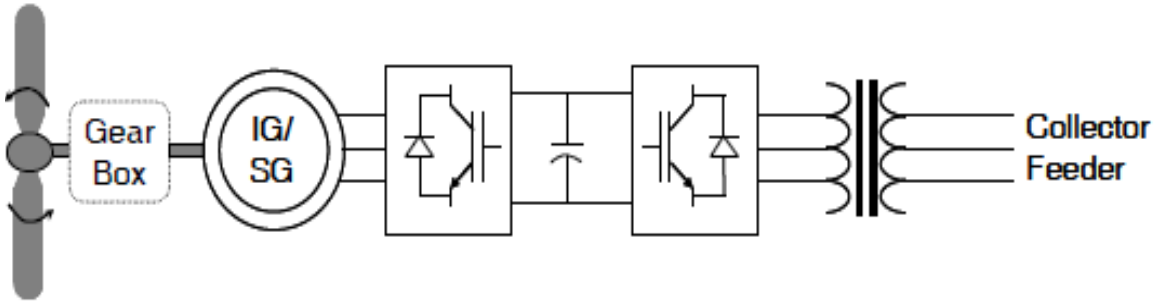


Type 2

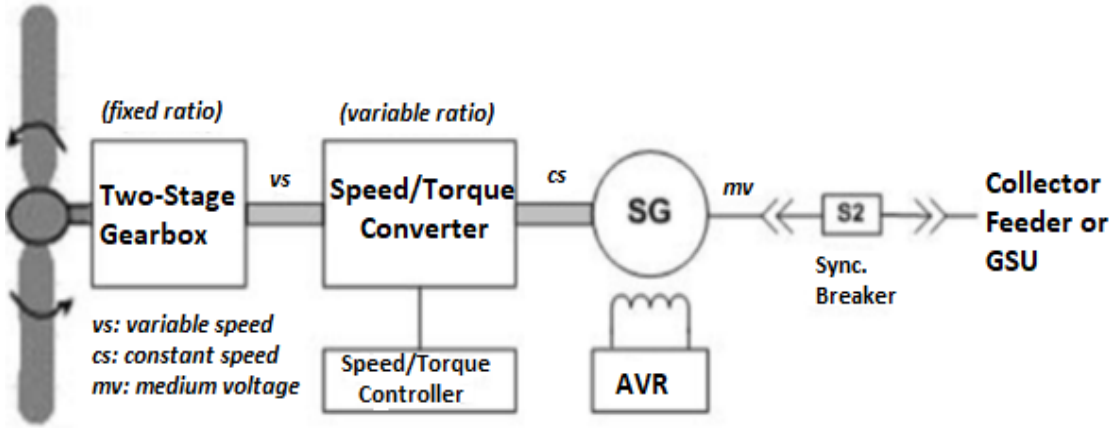
Type 3 Wind Turbine Generator



Typical Wind Turbine Generator Types

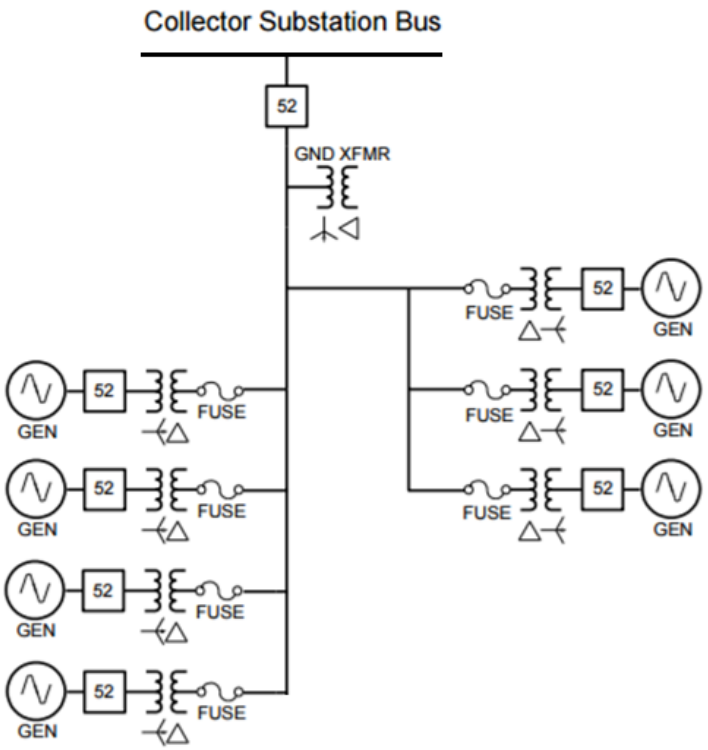


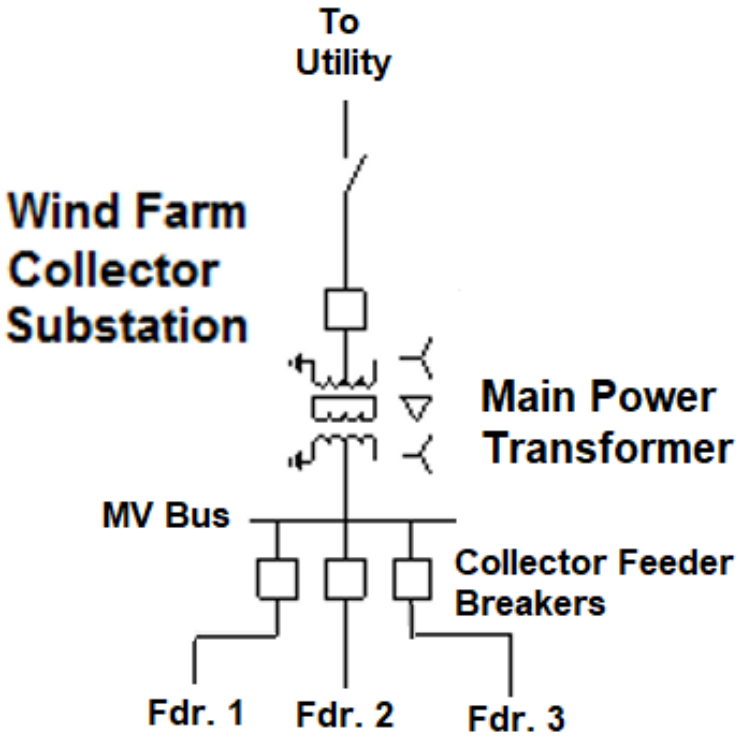
Type 4



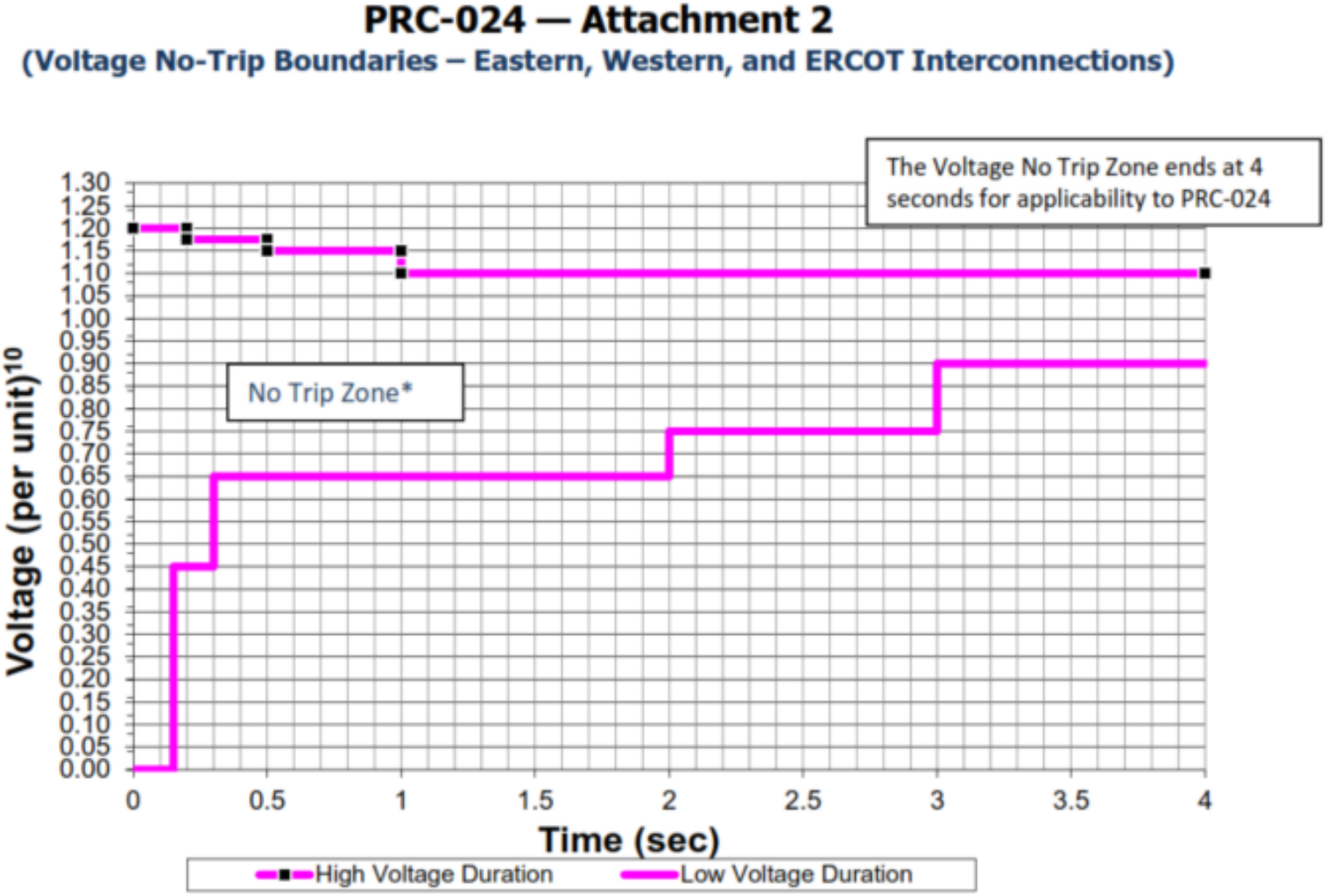
Type 5

Collector System Grounding

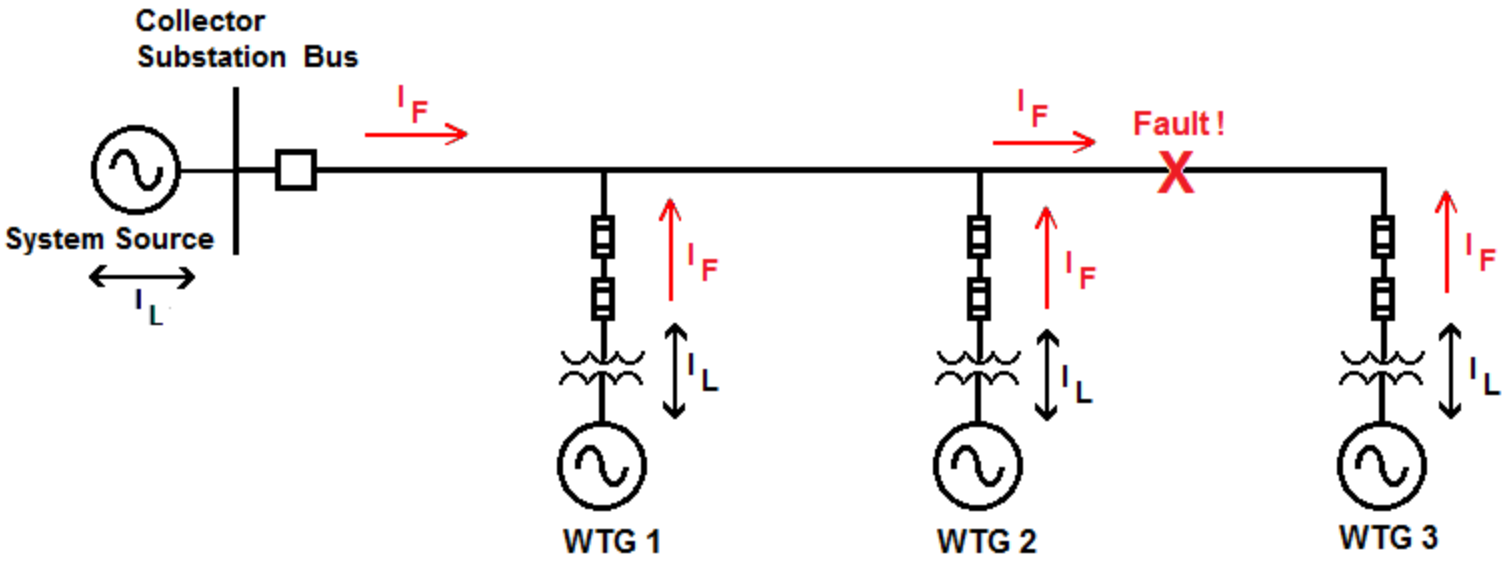




Voltage Ride-Through Requirements



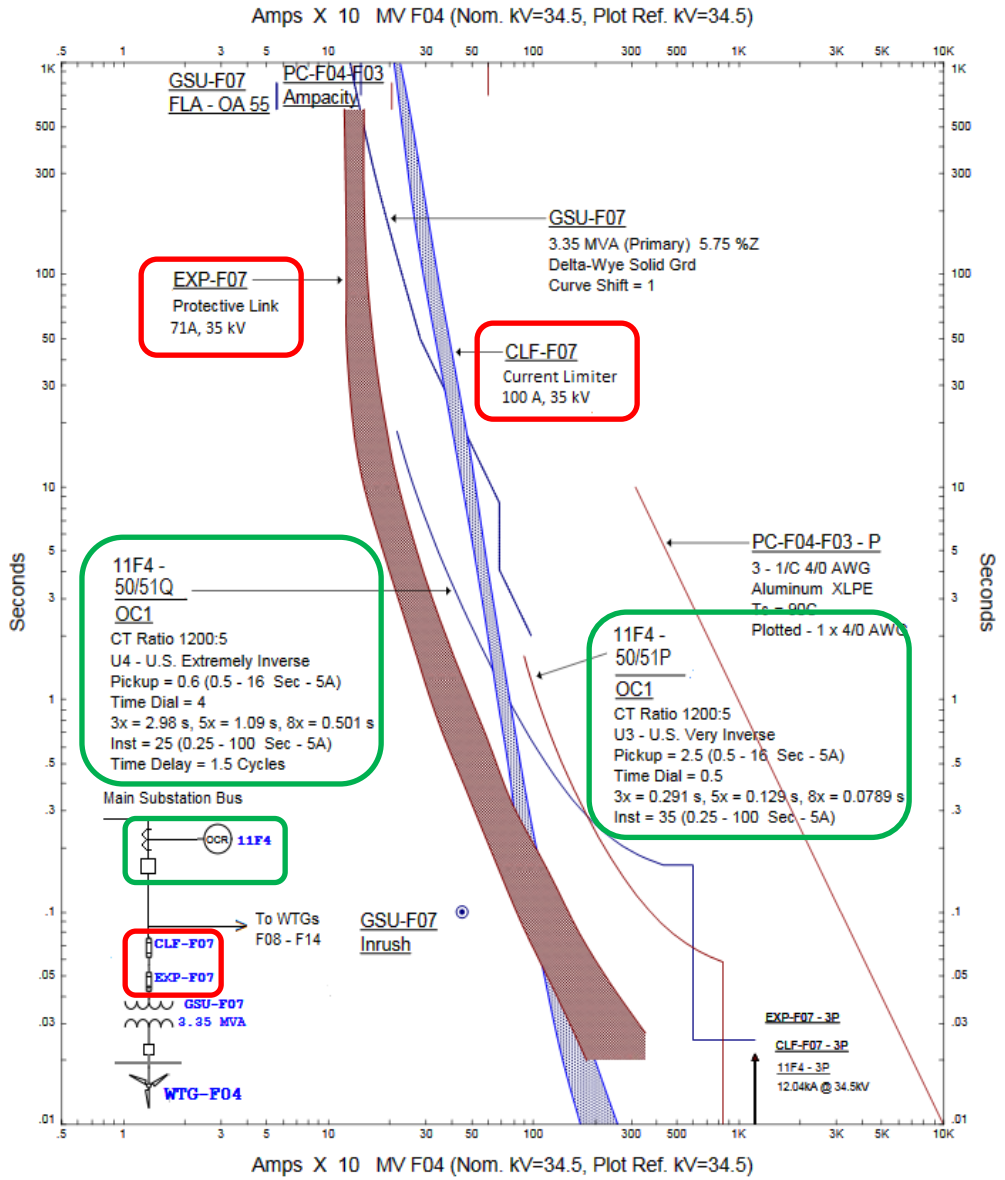
Collector feeders operate with both radial and network characteristics



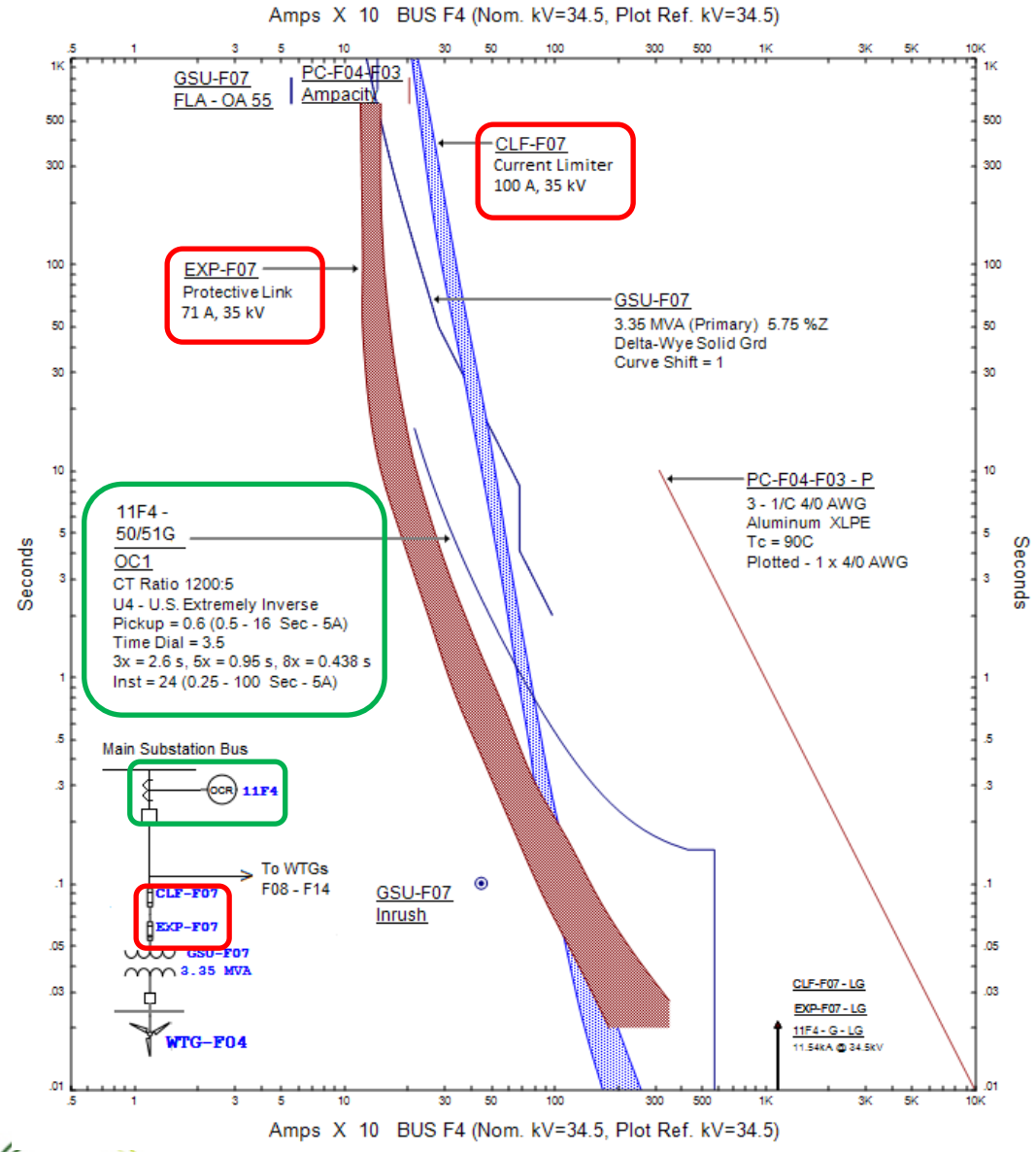
Overcurrent Protection Settings for Collector Feeders

Non-directional Overcurrent Relay Settings:

- **51P:** Pickup above load current and time dial selected to coordinate with WTG GSU transformer.
- **50P:** Pickup to detect a 3-ph fault at the end of the feeder but above combined GSU transformer inrush current.
- **51G (51N):** Pickup 10-30% of 51P pickup but above the min current at which the GSU expulsion fuse begins to blow. Curve and time to coordinate with the expulsion fuse.
- **50G (50N):** Set to detect a SLG fault at the end of the feeder but high enough to avoid misoperation from CT or system unbalance current when GSU transformers are energized.
- Negative-sequence overcurrent elements may also be used



Non-directional Phase and Negative Sequence TOC Coordination With WTG Fuses

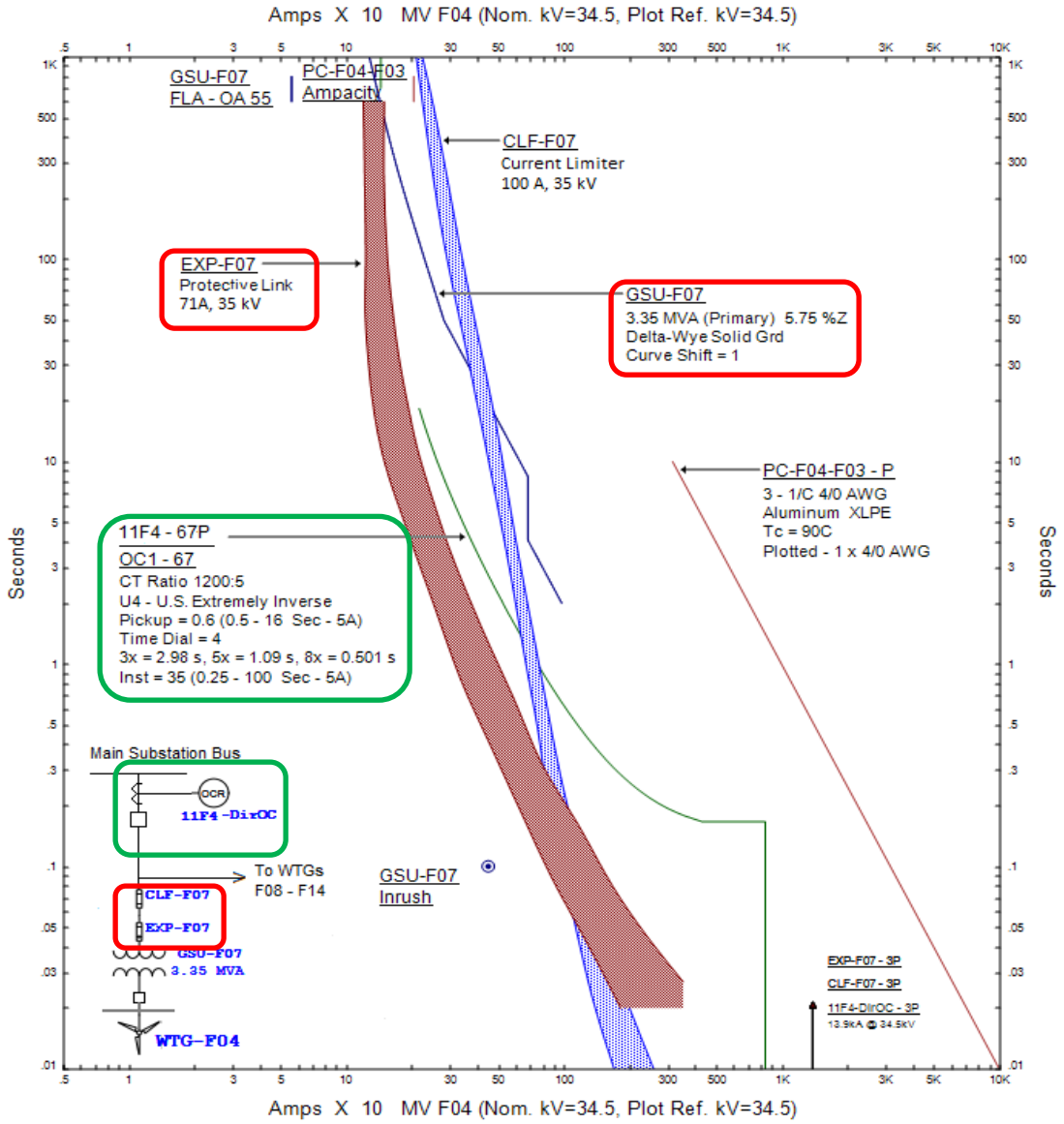


Non-directional Ground TOC Coordination With WTG Fuses

Overcurrent Protection Settings for Collector Feeders

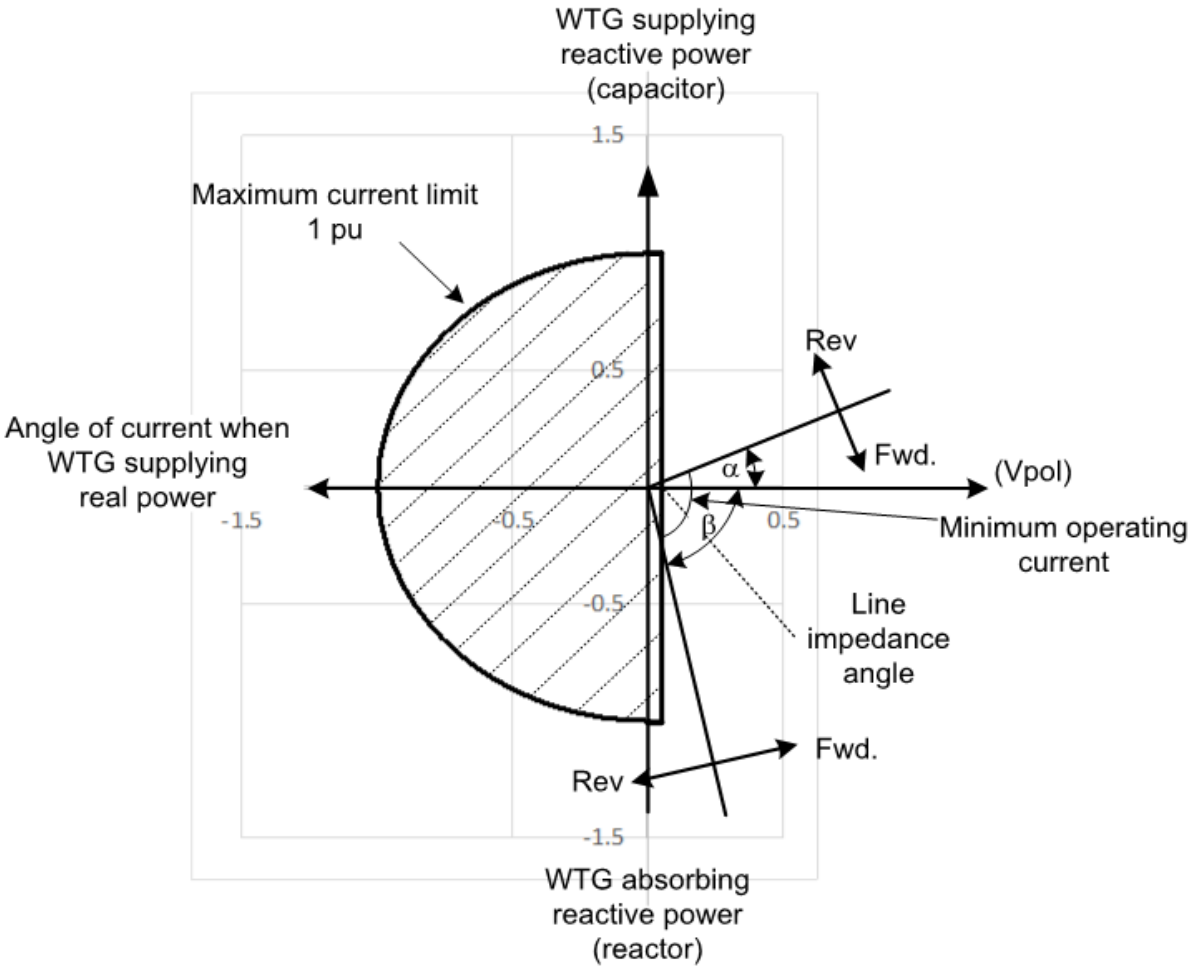
Directional Overcurrent Relay Settings:

- **Phase Time Overcurrent 67PT:** Pickup set below the collective WTG capacity for the collector feeder but above the minimum current at which the GSU expulsion fuse begins to blow. Coordinate with the expulsion fuse.
- **Phase Instantaneous Overcurrent 67PI:** Pickup low enough to detect a 3-ph fault at the end of the feeder but above the combined GSU transformer inrush current.
- **Ground Time Overcurrent 67GT (67NT):** Set the same as 51G (51N).
- **Ground Instantaneous Overcurrent 67GI (67NI):** Set the same as 50G (50N).
- **Directional Supervision Settings** must be selected with care to accommodate generator VAR outputs

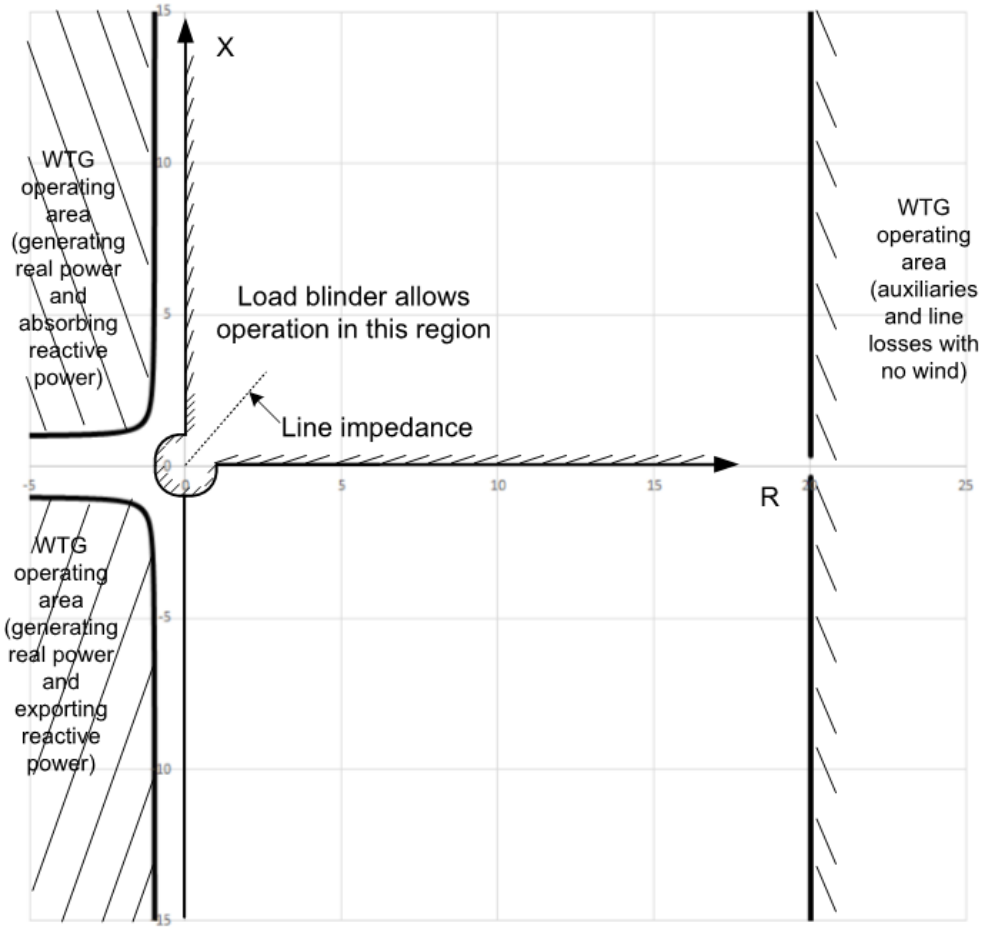


Directional Phase TOC Coordination With WTG Fuses

Phase Directional Element 67P With Adjustable Directional Blinders

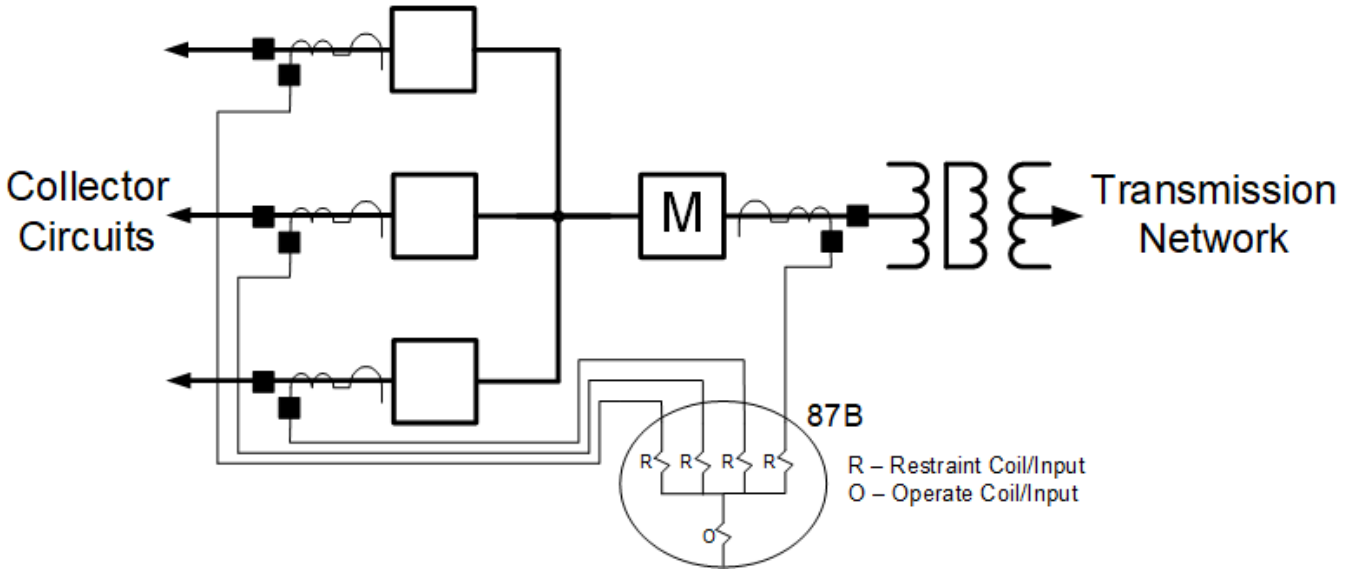


R-X Diagram Showing Normal Operating Regions of WTG and Example Positive Sequence Impedance Measuring Load Blinding Characteristic



Bus Protection

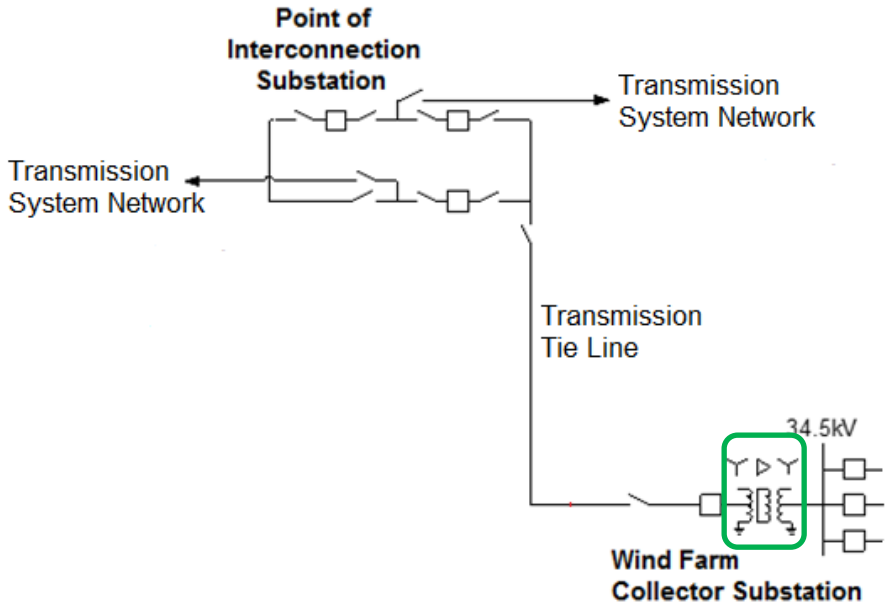
- Large power transformer size pushes the bus fault duty to significant levels which drives the need of high-speed clearing
- Zone-Interlocked Scheme
- Percentage-Restrained Differential
- High-Impedance Differential



Transmission Tie Line Protection

Challenges for Transmission Line Protection

- Variability of source strength due to the variability of the wind.
- Low positive-sequence fault current contribution from some WTGs.
- Little or unreliable negative-sequence fault current contribution from some WTGs.
- Zero-sequence fault current contribution may or may not be present, depending on the wind farm transformer connection.



Possible Transmission Line Protection Solutions

- Line Current Differential
- Weak infeed echo/trip logic for permissive overreaching transfer trip schemes
- Direct transfer trip
- Backup time delayed undervoltage (or overvoltage) protection
- Ground time overcurrent protection

Conclusions

- The protection of wind electric plants can be unique and challenging due to the following:
  - Composed of numerous relatively small generators distributed geographically over a wide area.
  - The WTGs predominantly in service have some degree of inverter interface affecting the fault current levels and characteristics.
  - Substation electrical layouts and grounding options depend on the WTG connection to the collector feeder system and on the wind power plant connection to the utility's power grid.
  - Applicable regulatory requirements, such as low-voltage ride through (LVRT)
- https://www.pes-psrc.org/kb/report/112.pdf
- https://resourcecenter.ieee-pes.org/publications/technical-reports/PES_TP_TR87_PSRC_050121.html

Questions?