

Analysis of Directional Protection on distribution feeders for DER interconnection and its performance during Multi-Fault Events

Marco Ciofani, Iraj Rahimi, Harjinder Sidhu
AltaLink, Canada

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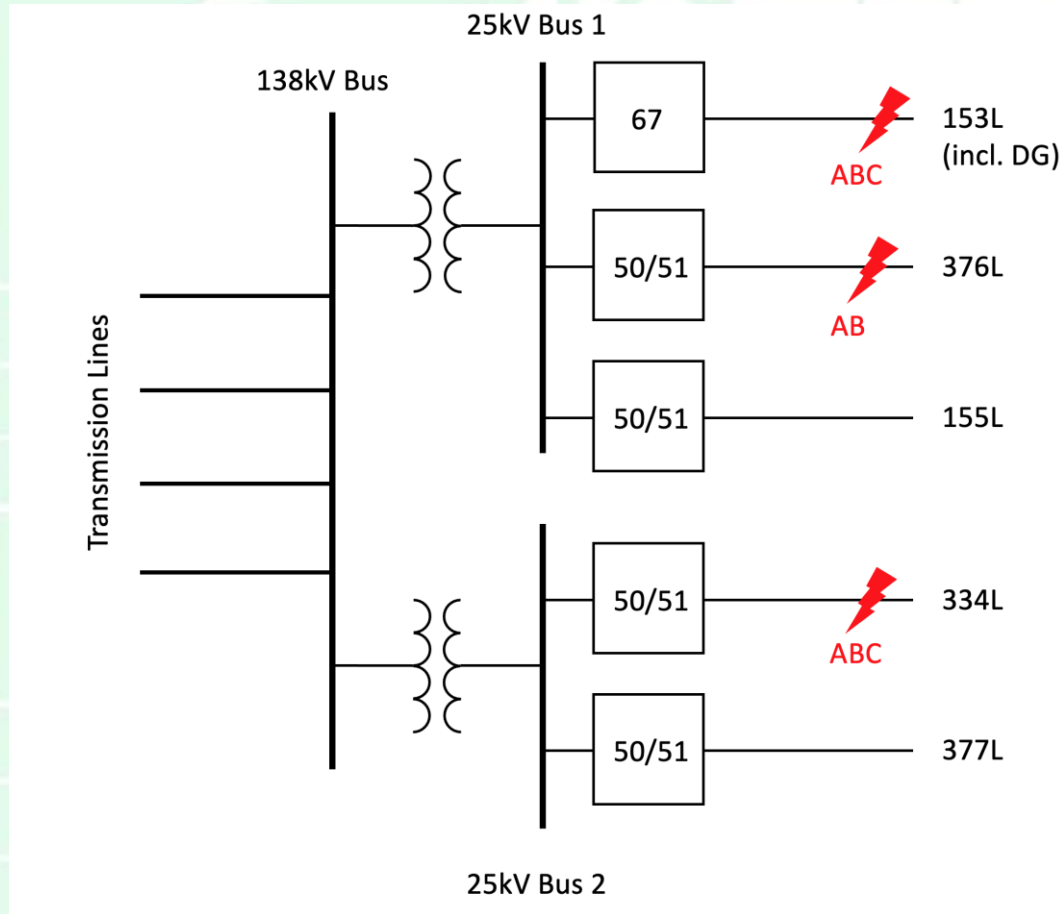
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- Event Overview
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Introduction

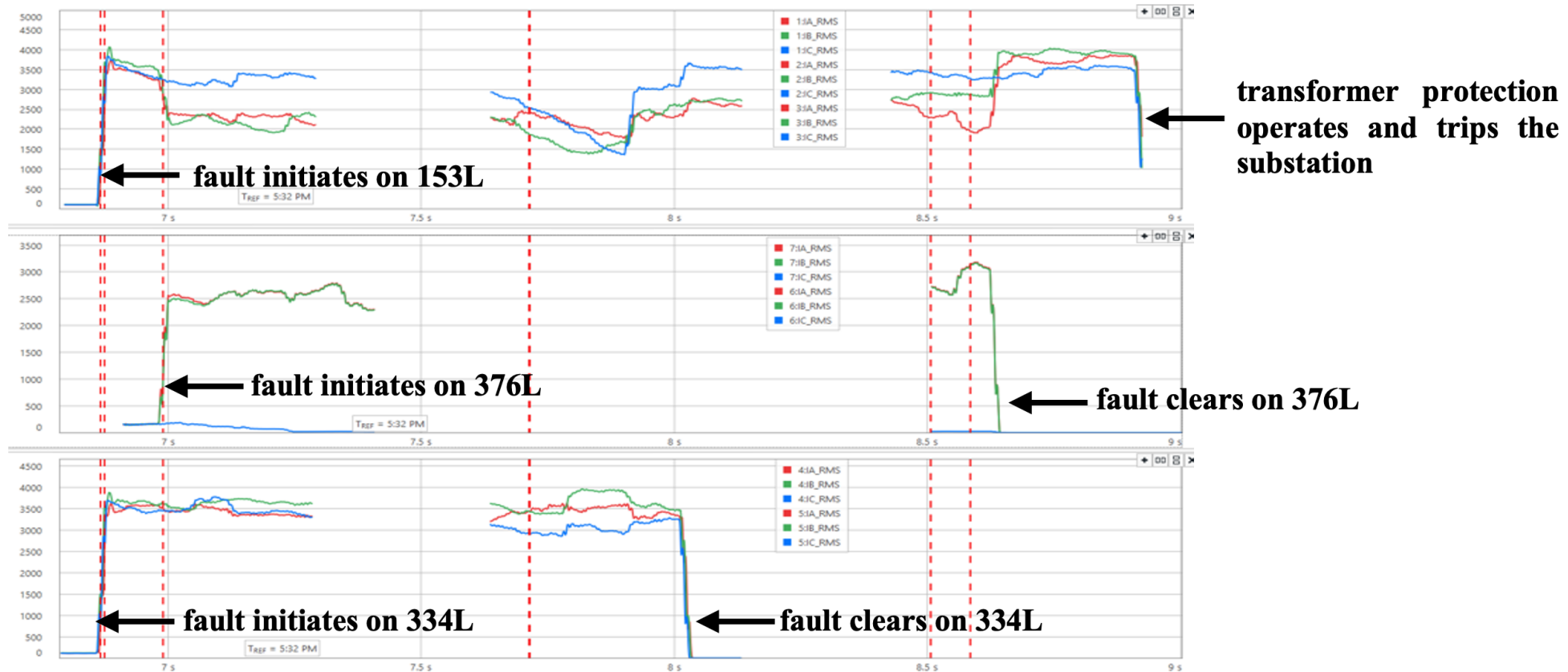
- Rapid increase in DER penetration onto the grid
- Standard practice to equip feeders with DG connections with directional overcurrent protection to prevent feeder from tripping for external faults
- Certain types of events can present challenges for feeder protection equipped with directional elements
- This paper presents an example of one such event which occurred in July 2021 when a multi-circuit fault occurred on a distribution system.

Event Overview

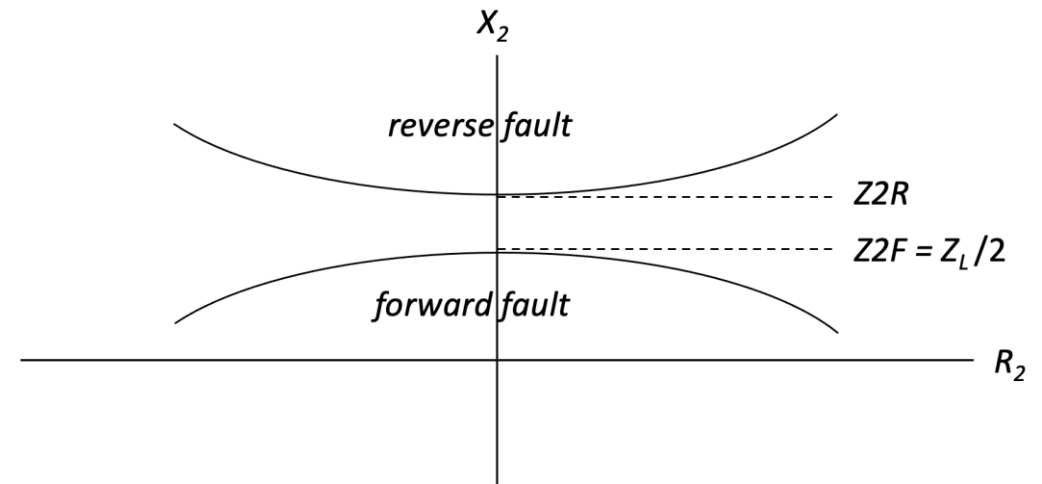
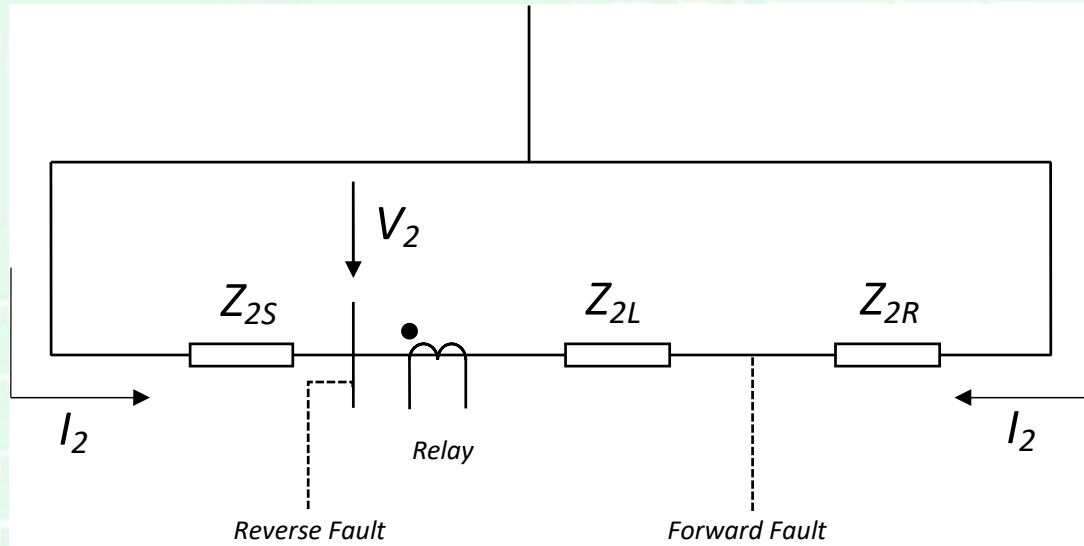


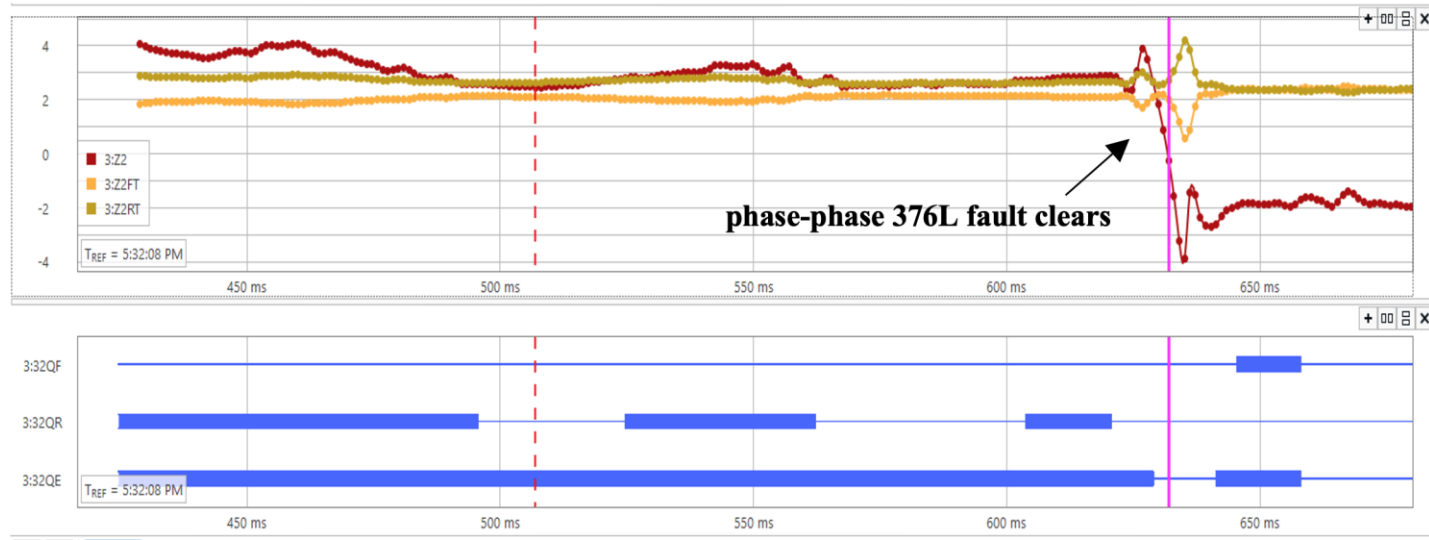
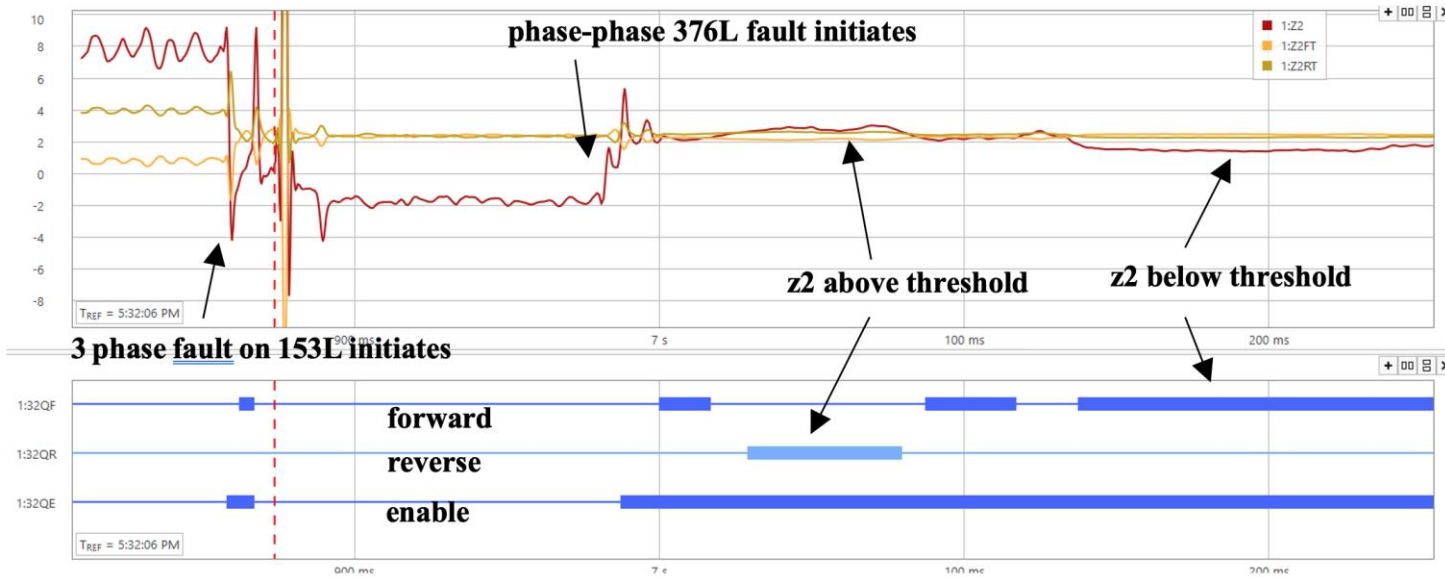
- Feeders are overhead lines and include multi-circuited structures
- Lightning caused faults to occur simultaneously on three different feeders
- 376L and 334L tripped as expected
- 153L failed to trip
- 138/25kV transformer backed up the feeder protection and tripped, causing sustained interruption to three feeders

Event Overview



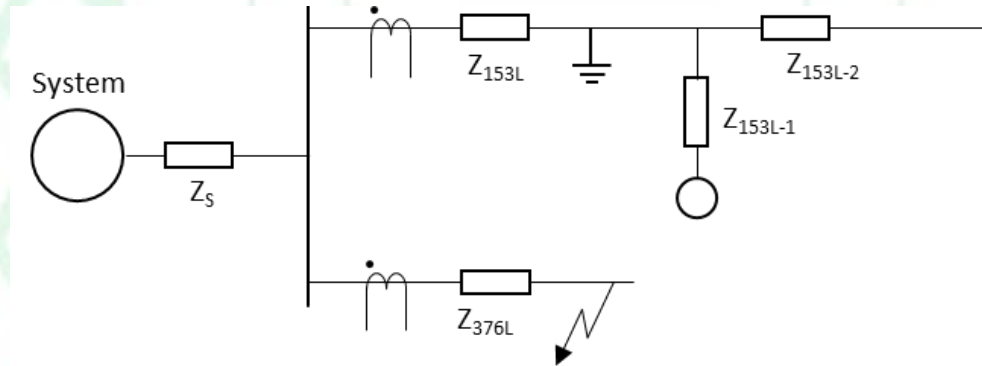
Event Analysis



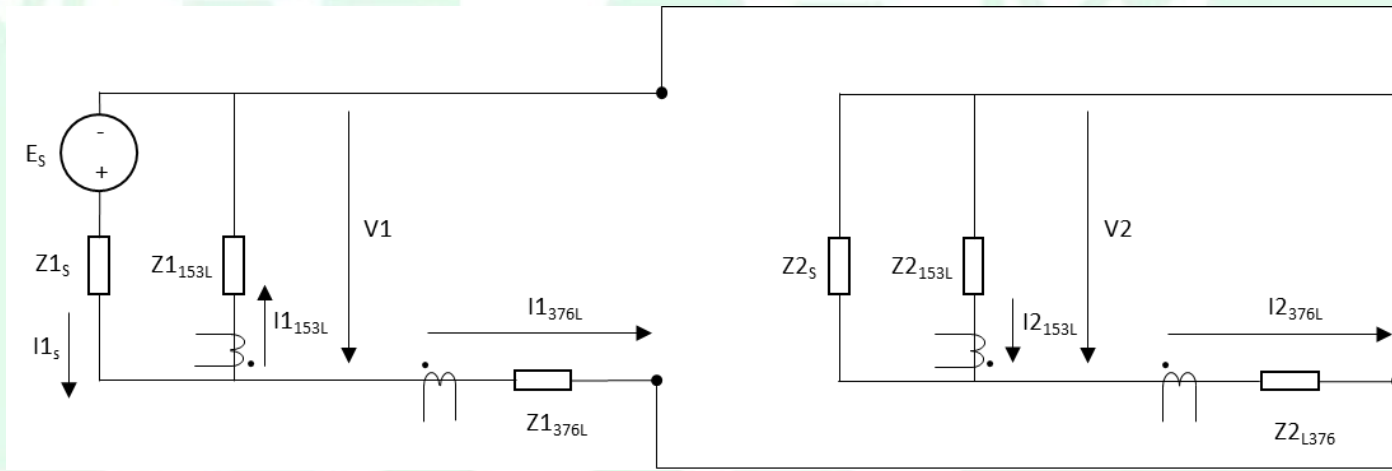


Event Analysis

Single Line



Sequence Network



Event Analysis

Measured vs Calculated Values

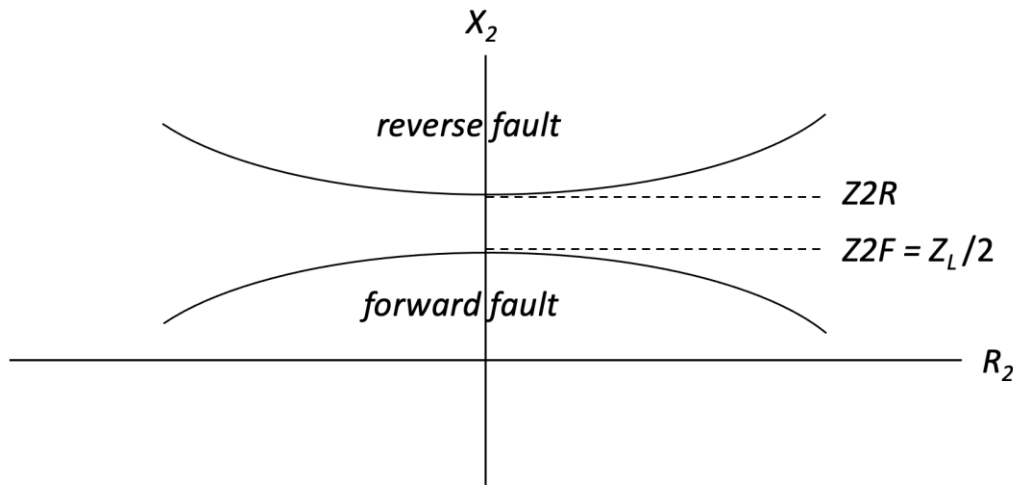
Line	Quantity	Measured	Calculated
376L	I1	1583 A	1341 A
	I2	1563 A	1341 A
	V1	6455 V	6149 V
	V2	1998 V	1661 V
153L	I1	2842 A	2426 A
	I2	653 A	656 A
	V1	6453 V	6149 V
	V2	1991 V	1661 V

Quantity	Measured	Calculated
Z2RT	2.64	2.51
Z2FT	2.11	2.24
z2	2.46	2.51

Event Analysis

$$Z_2 = \left| \frac{\bar{V}_2}{-\bar{I}_2} \right| = \left| \frac{-\bar{I}_{2153L} * \bar{Z}_{2153L}}{-\bar{I}_{2153L}} \right| = \bar{Z}_{2153L}$$

- Z2 for 153L relay is equal to the negative sequence impedance of the section of line between the relay and the balanced fault on 153L
- The fault occurred approximately halfway down the line, therefore Z2 was close to the Z2F threshold while the unbalanced fault on 376L fault was present



Event Analysis

Factors Affecting the Event

- Simultaneous multi-phase faults on multiple feeders at the same time
 - Typically one or two per year where the it caused transformer backup protection to operate. More where impact was limited to the feeders.
 - Generally when they do occur, they are multi-phase faults
- Order of the faults
 - Balanced fault on 153L and unbalanced on 376L
- Location of the faults
 - Fault was halfway down the line

Mitigations

- Increase Z2F threshold to increase the dependability
 - Potential loss in security, more likely to trip for external faults
 - Likely not a good trade-off
- Communication between relays and logic to interpret multi-feeder fault conditions
 - Additional wiring, logic, and complexity

Conclusions

- Multi-circuit faults have the potential to defeat substation protection coordination where directional elements are implemented on the feeder relays.
- The possibility of this occurring depends on the type and location of the faults
- This was a rare event, but may become more common as DG penetration into the system increases
- Mitigations are possible, but in general may offer more downsides than benefits.