Impact of Distributed Energy Resources on Arc Flash Incident Energy

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Dominion Energy
PJM Ride-Through Workshop

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Dominion Energy, System Protection

Agenda

- Introduction
- Assumption / Set-up
- Modeling Variables
- Variable Impacts
- Mitigation
- Conclusions

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Introduction

- Overhead Line Distribution Energized Work
- NESC 410A3 – Employer is responsible to determine exposure.
- Personal Protection Equipment rating greater than the exposure
- Arc Flash Incident Energy < 8 cal/cm^2

Effective Cover Up Performed on Overhead Lines
(Dominion Energy Training Facility)

Assumption/ Set-up

- All 9 case studies: 34.5 $kV_{L\text{-}L}$
- Used ArcPro
- Single phase-to-ground faults*
- Bolted fault – no fault impedance added
- Open air fault
- Arc gaps and Working distances – follows NESC 410
- DER stays online after utility opens
- Fault is sustained

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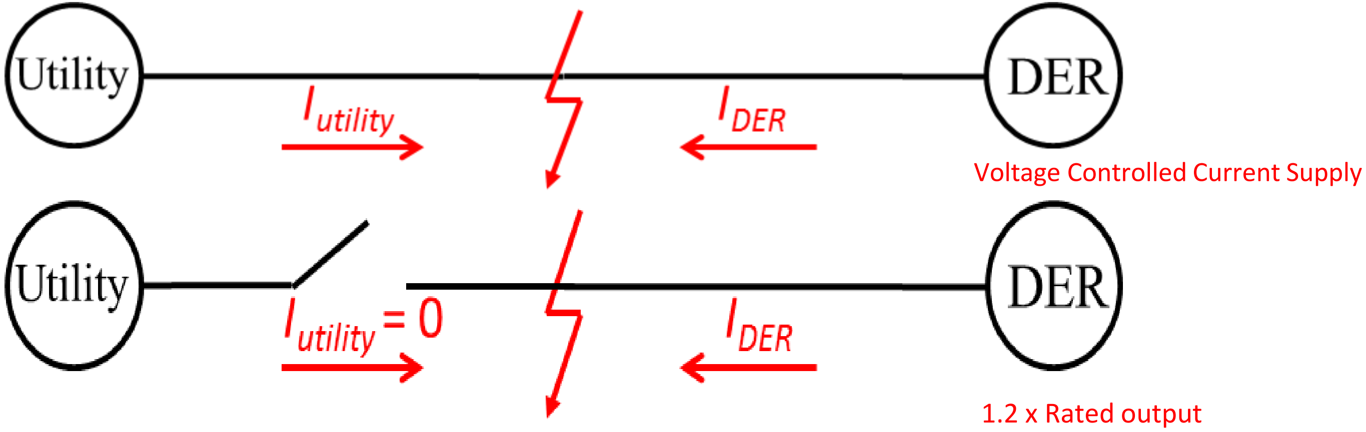
Assumption/ Set-up

•DER Comes offline after utility is disconnected.

PART A:

PART B:
(Run-on Time)



$$E_A + E_B = E_C$$

(Assumes a sustained arc)

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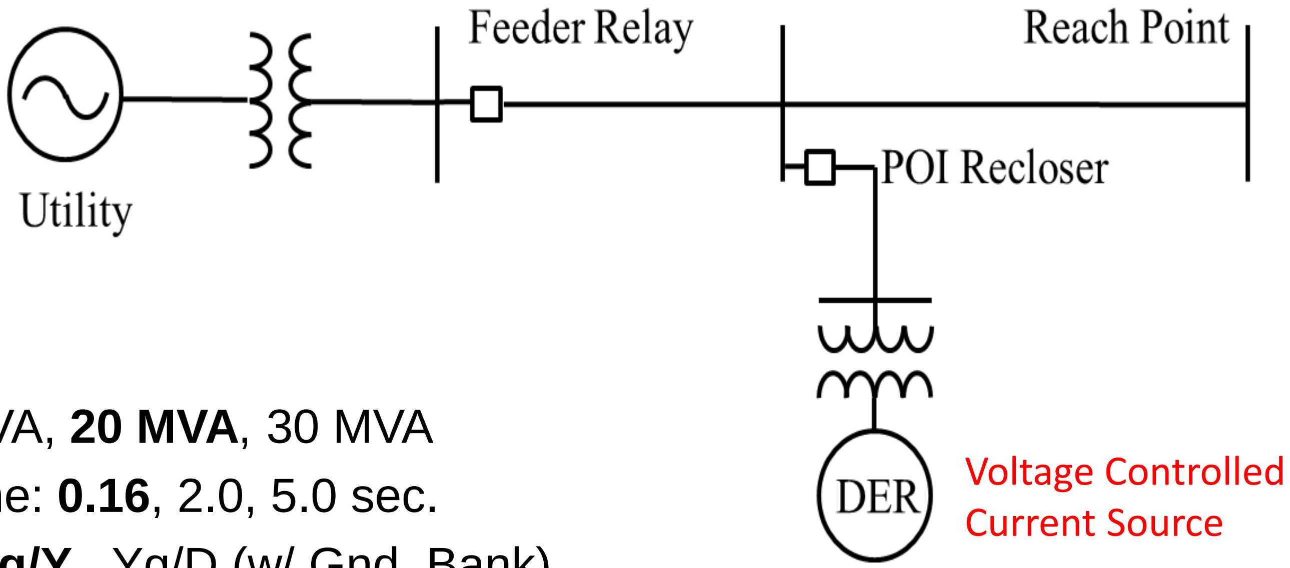
Modeling Variables

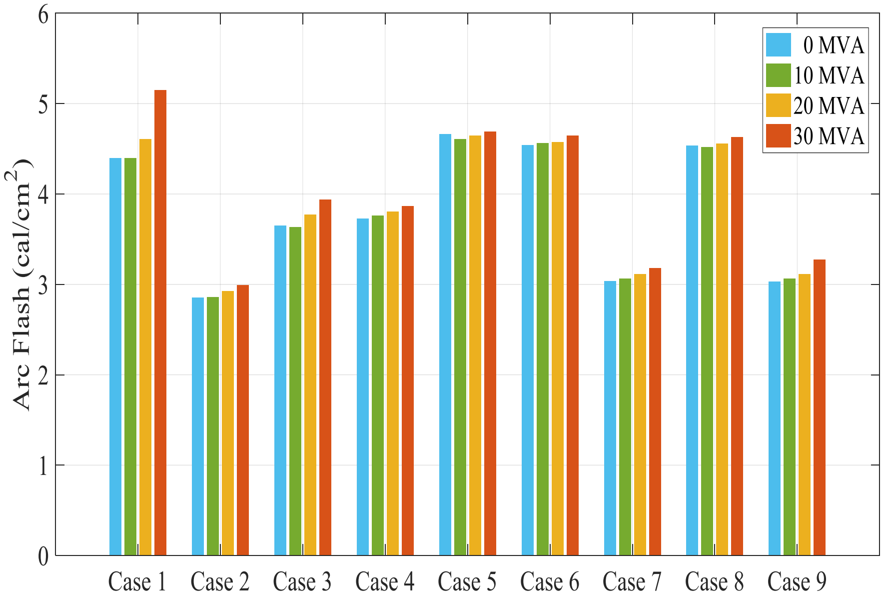


- DER Size: 10 MVA, **20 MVA**, 30 MVA
- DER Run-on Time: **0.16**, 2.0, 5.0 sec.
- DER GSU Tx.: **Yg/Y** , Yg/D (w/ Gnd. Bank)

DER Viable Impact: **Size**

Fixed: Run-on Time – 0.160 s & GSU – Yg/Y

- 30 MVA - 5.70% increase
- 20 MVA - 2.13% increase
- 10 MVA - 0.20% increase
- Case 1's 30 MVA study causes 17.18% increase



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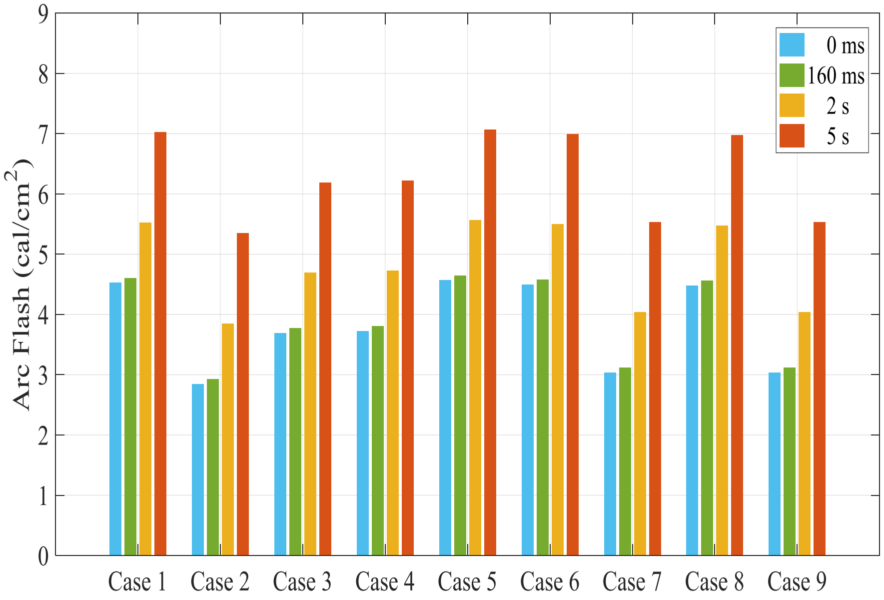
DER Viable Impact: **Run-on Time**

Fixed: Size – 20MVA & GSU – Yg/Y

- 0.160s - 2.7% increase
- 2 s - 27.0 % increase
- 5 s - 67.7 % increase



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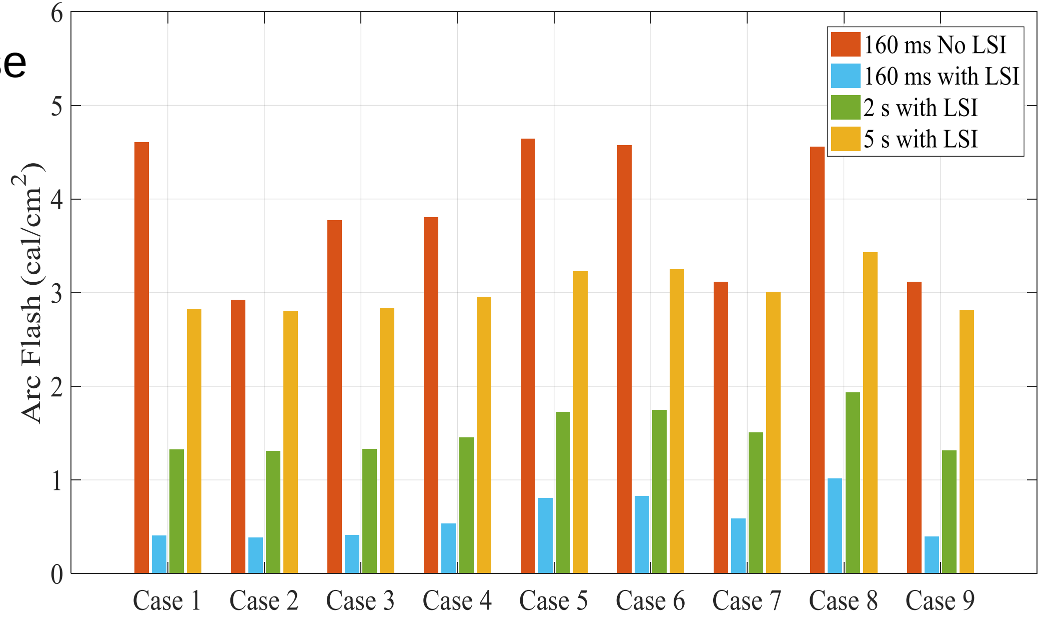
DER Mitigation: **Low Set Instantaneous (LSI)**

- 160 ms – 15.13 % of the base case
- 2 s – 39.48% of the base case
- 5 s – 79.19% of the base case



Cons:

- Protection coordination is sacrificed at the expense of safety

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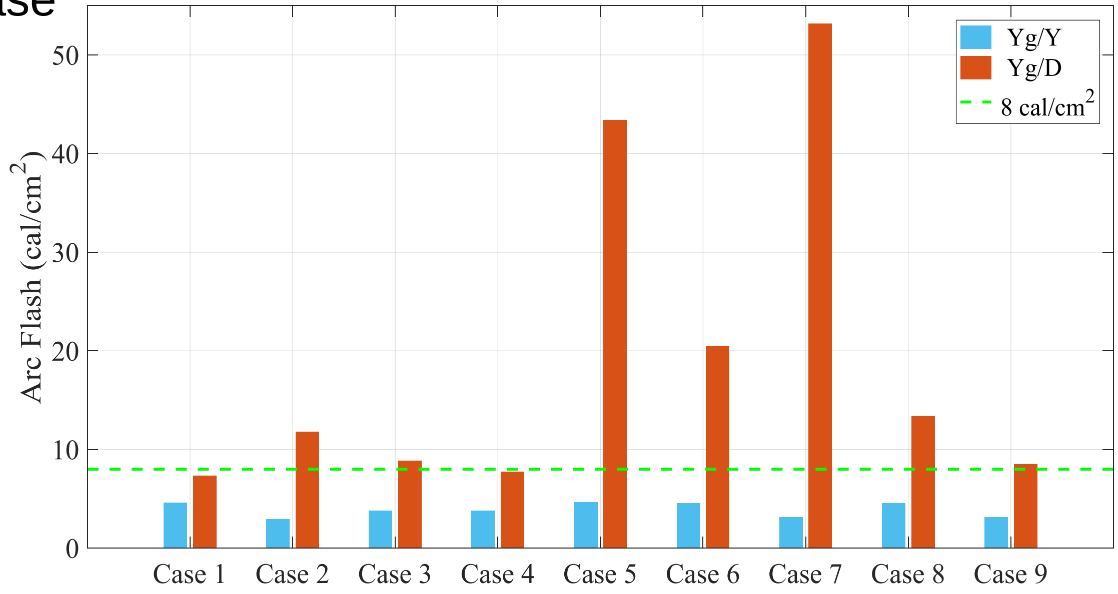
DER Viable Impact: **Transformer Configuration**

Fixed: Size – 20MVA & Run-on Time – 0.160 s

- Yg/ D - 418 % increase

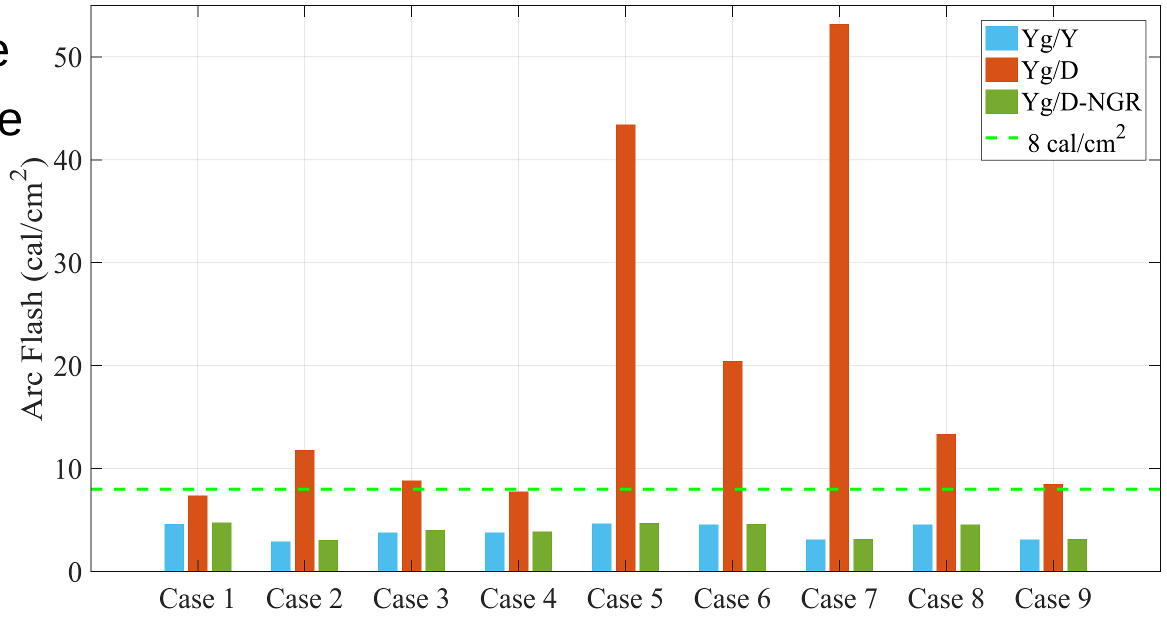


DER Mitigation: **NGR (Neutral Grounding Resistor)**

- Yg/D - 418 % increase
- w/ NGR - 2.42 % increase

Cons:

- Can be inadvertently bypassed
- Will de-sensitize ground settings



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Conclusion

- Increased DER MVA size increases exposure:

  (10 MVA) 0.20%, (20 MVA) 2.13%, (30 MVA) 5.70%

- Longer Clearing times will substantially increase exposure:

  Approx. **14% increase in cal / cm^2** for each (1s) second @ 34.5 kV and 20MW

- Transfer Trip is preferred to control exposure from DER
- Yg / D requires NGR to manage exposure
- Yg-Y is preferred
- Low Set INST. decreases exposure (in Part A) by sacrificing downline coordination

Why we care….

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Supplement-A

Table 410-2—Clothing and clothing systems—voltage, fault current, and maximum clearing time for voltages 1.1 kV to 46 kV ac ①
(See Rule 410A3.)

Phase-to-phase voltage (kV)	Fault current (kA)	4-cal system	8-cal system	12-cal system
		Maximum clearing time (cycles)	Maximum clearing time (cycles)	Maximum clearing time (cycles)
1.1 to 15	5	46.5	93.0	139.5
	10	18.0	36.1	54.1
	15	10.0	20.1	30.1
	20	6.5	13.0	19.5
15.1 to 25	5	27.6	55.2	82.8
	10	11.4	22.7	34.1
	15	6.6	13.2	19.8
	20	4.4	8.8	13.2
25.1 to 36	5	20.9	41.7	62.6
	10	8.8	17.6	26.5
	15	5.2	10.4	15.7
	20	3.5	7.1	10.6
36.1 to 46	5	16.2	32.4	48.6
	10	7.0	13.9	20.9
	15	4.3	8.5	12.8
	20	3.0	6.1	9.1

①These calculations are based on open air phase-to-ground arc. This table is not intended for phase-to-phase arcs or enclosed arcs (arc in a box).

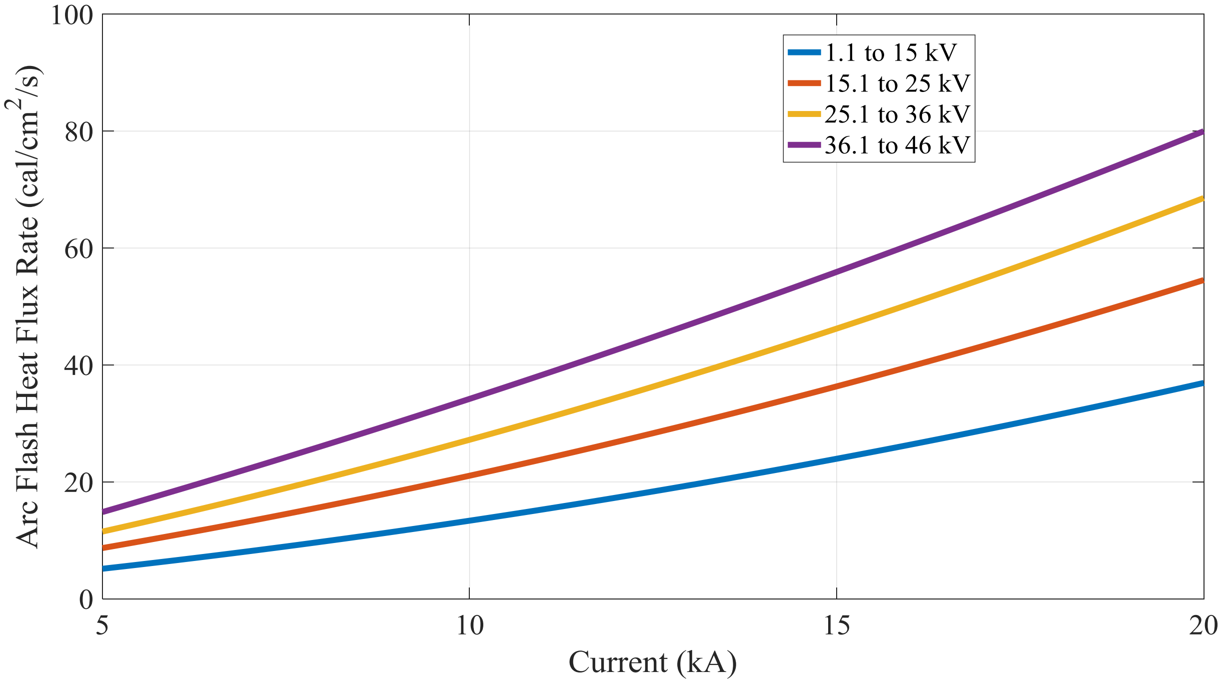
These calculations are based on a 15-in separation distance from the arc to the employee and arc gaps as follows: 1 kV to 15 kV = 5.08 cm (2 in), 15.1 kV to 25 kV = 10.16 cm (4 in), 25.1 kV to 36 kV = 15.24 cm (6 in), 36.1 kV to 46 kV = 22.86 cm (9 in). See IEEE Std 4-1995.

These calculations were derived using a commercially available computer software program. Other methods are available to estimate arc exposure values and may yield slightly different but equally acceptable results.

The use of the table in the selection of clothing is intended to reduce the amount or degree of injury but may not prevent all burns.

Supplement-B

Derived from NESC Table 410-2



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Supplement-C

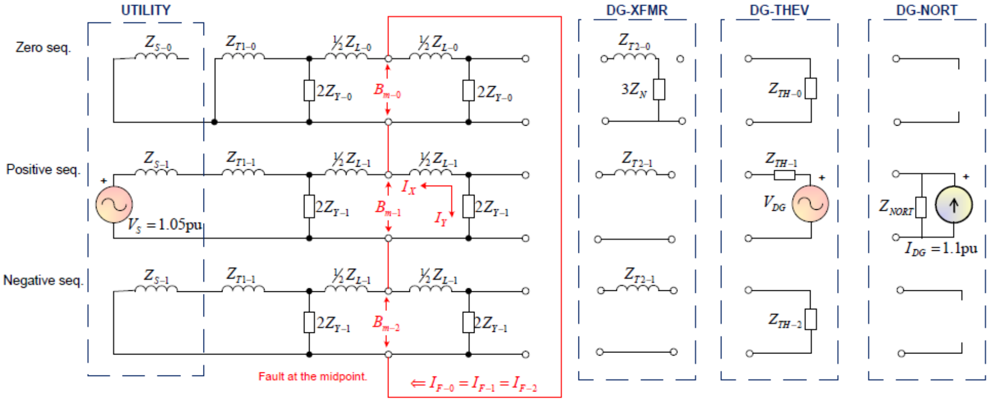

Figure 2. Sequence networks for a SLGF at feeder midpoint, with wye impedance grounded/delta interconnection transformer shown and either a Thevenin or Norton DG equivalent.

Z_{L-0} = zero sequence line impedance
Z_{L-1} = positive sequence line impedance
Z_{s-0} = zero sequence utility impedance
Z_{s-1} = positive sequence utility impedance
Z_{T1} = substation transformer impedance

Z_{T2} = PV transformer impedance
Y_0 = zero seq line susceptance + load
Y_1 = positive seq line susceptance + load
$I_{F-0,-1,-2}$ = fault current

Reference:
IEEE. Laura Wieserman, *Student Member*, IEEE, and T.E. McDermott. *“Fault Current and Overvoltage Calculations for Inverter-Based Generation Using Symmetrical Components.” -*

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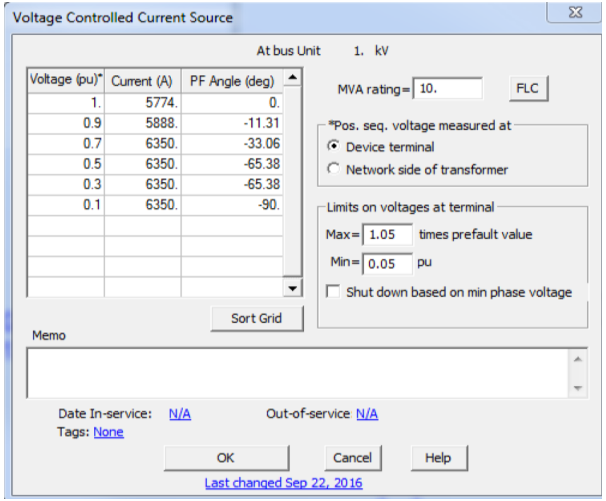
Supplement-D

Inverter Modeling

- Inverters modelled as Voltage Controlled Current Source

- Similar and following ASPEN Recommendation:



Voltage (pu)*	Current (A)	PF Angle (deg)
1.	5774.	0.
0.9	5888.	-11.31
0.7	6350.	-33.06
0.5	6350.	-65.38
0.3	6350.	-65.38
0.1	6350.	-90.