Stiffness Factor Test

A Screening Tool for Evaluation of Need for Impact Study Analysis for Intermittent DER Interconnections

Presented to TSRG Meeting May 16, 2017

Stiffness Factor Test

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- A screening tool that Eversource employs, in addition to other screening criteria in the Tariff and engineering judgement, to determine the Need for Impact Study analyses for intermittent DER applications
- A measure of expected power quality (PQ) impacts for intermittent DG interconnections (e.g. solar and wind). Not needed for dispatchable or load-reducing DER interconnections (e.g. CHP, synchronous machines).
- Evaluates the effects of interconnection of a one (1) DER interconnection at one primary point of common coupling (PCC).
- A pre-existing power flow or protection model of the distribution system (CymDist, Synergee, PSS/Adept, ASPEN, etc.) may be required.
- It is a well-known test. See NREL presentation "High-Penetration Photovoltaic Standards and Codes Workshop" page 25 "Ratios and Their Uses" http://www.nrel.gov/docs/fy10osti/48378.pdf
- The other criteria include: Existing DER saturation level of the circuit / substation bus with existing / approved for interconnection applicants, results of last impact study for projects queued just before, fault current contribution, light load voltage rise analysis, concern for islanding, etc.

Identify Study Criteria – Example: System Stiffness

- A screening criterion to determine whether detail studies are required to assess DG impact on power quality:
  - The ratio between the available utility system fault current (I_{sc}) at point of DG connection and the DG's full load rated output current (I_{DG})

$$Stiffness\ \ Factor = \frac{I_{sc}}{I_{DG}}$$

Stiffness Factor (SF)	Recommendation
SF >250	**Insignificant:** Absolutely no concern that flicker or voltage change will be an issue for any type of DG source
100 < SF≤ 250	**Nearly Insignificant:** Very little concern unless DG is started/stopped frequently or has unusual fluctuations
50 < SF≤ 100	**Minor Concern:** Moderate concern for fluctuating sources such as wind and PV. Will need to assess rates of fluctuations and start/stop cycles but still probably not an issue in most cases
25 < SF≤ 50	**Significant Concern:** Any DG source connecting with an SF in this range will need serious analysis of planned start/stop cycles and output fluctuations and may need some mitigation equipment
15 < SF≤ 25	**Very Significant Concern:** DG in this range can cause serious voltage flicker and fluctuations. Mitigation equipment and/or system changes probably are needed
SF ≤ 15	**Extreme Concern:** Voltage changes may be so severe that project is not viable without extreme application of mitigation devices or feeder upgrades

Stiffness Factor Test

- **Definitions**
- <u>Available Fault Duty,</u> $\mathbf{I_{sc}}$
- Maximum available fault (short circuit) current at the requested point of common coupling. Includes contributions of existing and previously queued DG applicants.
- Can be a 3-phase fault, 2-phase fault, 2-phase to ground fault, or single line to ground fault (most common). The lowest value is used in the calculation.
- A function of the location and strength of the transmission system where the source substation is located, the impedance of the bulk substation, and the length, topology, and impedance of the distribution circuit from the substation to the requested point of common coupling.

CymDist Model – Example 13.2kV Circuit

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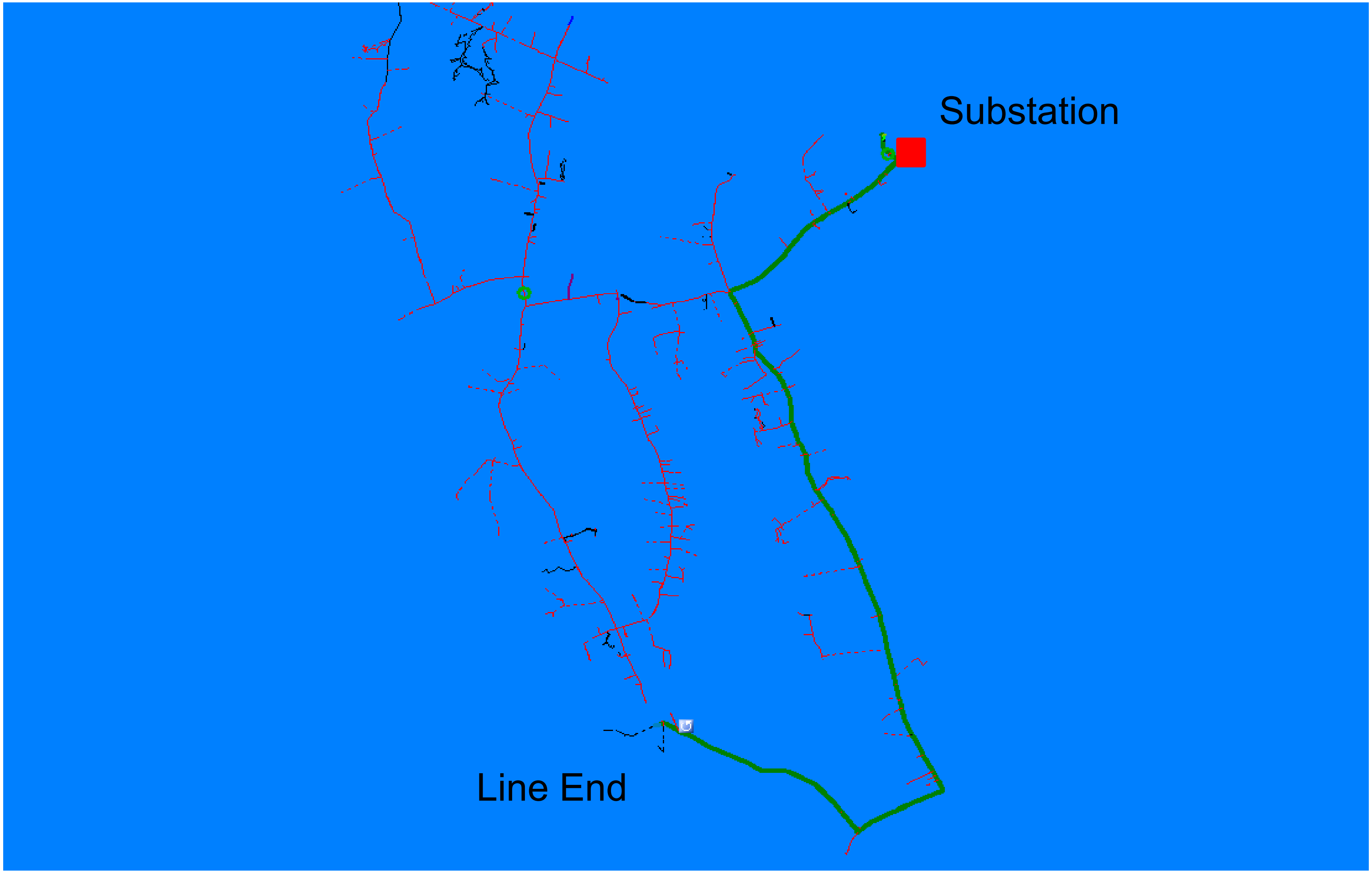

CymDist Model – Example 13.2kV Circuit

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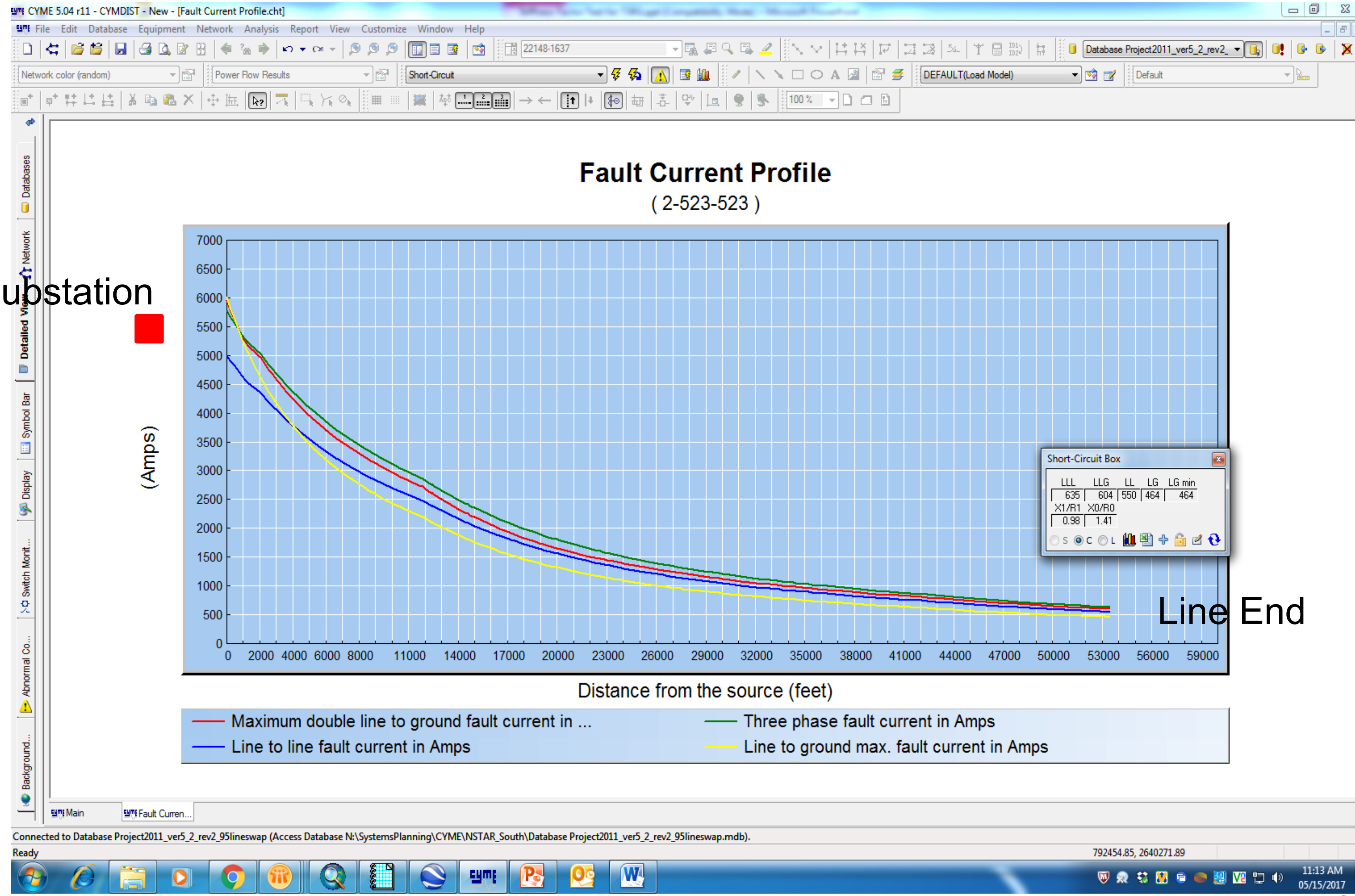

Stiffness Factor Test

- **Definitions**
- DG full load primary output current, **I_{DG}**
- The maximum primary load Amperes for the DER at the requested point of common coupling with the DER at its full claimed kW(AC) output.
- Example for a 1,000 kW(AC) PV array

$$I_{DG} = \frac{1,000,000}{\sqrt{3}*4160} = 139 \text{ Amps at } 4.16\text{kV}$$

$$I_{DG} = \frac{1,000,000}{\sqrt{3}*13,800} = 44 \text{ Amps at } 13.8 \text{ kV}$$

$$I_{DG} = \frac{1,000,000}{\sqrt{3}*23,000} = 25 \text{ Amps at } 23.0 \text{ kV}$$

Example Calculation - #1

2 MW Solar Interconnection at the End of A Long 13.2kV Feeder
No other applicants queued ahead on the feeder, other applicants same bus section
Fails stiffness factor test and requires impact study

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Example 1.99 MW PV Array

Near the End of a Long 13.2kV distribution circuit

SYSTEM STIFFNESS FACTOR CALCULATION (FED FROM FISHER ROAD SUBSTATION, #523 CIRCUIT)

Existing Fault Duty at Point of Interconnection (POI)

LLL-G	1032	Amperes
LLL	969	
LL-G	729	
LG	729	

Short-Circuit Box

LLL	LLG	LL	LG	LG min	
1032	969	894	729	729	
X1/R1	X0/R0	R1	X1	R0	X0
1.38	1.93	4.5665	6.2931	8.0765	15.5877

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1.99 MW PV ARRAY

	1.99	MW	
Max Isc	1032	Amperes	
Min Isc	729		
I FL @ 13.2kV	87.0	Amperes	
Stiffness Factor	11.9	(using Max Isc)	(Extreme Concern)
(Isc / IFL)	8.4	(using Min Isc)	(Extreme Concern)

Example Calculation - #2

2 MW Solar Interconnection at the End of A Long 23kV Feeder
Stiffness Factor Test Result Borderline BUT in a cluster with 2 other applicants
Area Saturated already with prior applicants, requires impact study

EXAMPLE 2 MW DER INTERCONNECTION

NEAR TAIL END OF 23KV DISTRIBUTION CIRCUIT

SYSTEM STIFFNESS FACTOR CALCULATION (FED FROM WEST POND #10 LINE #929 CIRCUIT)

Existing Fault Duty at Point of Interconnection (POI)

LLL-G	2074	Amperes	
LLL	1880		
LL-G	1794		
LG	1422		
		2.0 MW PV ARRAY	
		2	MW
Max Isc		2074	Amperes
Min Isc		1422	
I FL @ 23kV		50.2	Amperes
Stiffness Factor		41.3	(using Max Isc) (Significant Concern)
(Isc / IFL)		28.3	(using Min Isc) (Significant Concern)

Short-Circuit Box

LLL	LLG	LL	LG	LG min	
2074	1880	1794	1422	1422	
X1/R1	X0/R0	R1	X1	R0	X0
2.54	2.44	2.3860	6.0627	5.8568	14.3011

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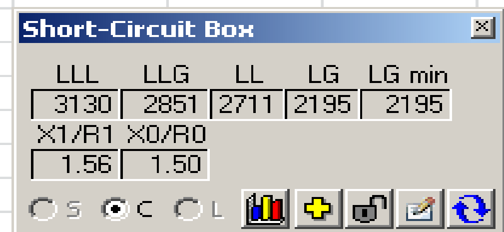
Example Calculation - #3

334 kW Solar Interconnect near tail end of 23kV distribution feeder; not a saturated area, interconnection small compared to fault duty at PCC, passes stiffness factor test no impact study required

EXAMPLE 334 KW PV ARRAY					
NEAR TAIL END OF 23KV DISTRIBUTION CIRCUIT					
SYSTEM STIFFNESS FACTOR CALCULATION (FED FROM DUXBURY #25 LINE)					
Existing Fault Duty at Point of Interconnection (POI)					
LLL-G	3130	Amperes			
LLL	2851				
LL-G	2711				
LG	2195				
		0.334 MW PV ARRAY			
		0.334			
Max Isc		3130	Amperes		
Min Isc		2195			
I FL @ 23kV		8.4	Amperes		
Stiffness Factor		373.3	(using Max Isc)		(Insignificant Concern)
(Isc / IFL)		261.8	(using Min Isc)		(Insignificant Concern)



Example Calculations - #4

296 kW Solar Interconnect on a 4.16kV stepdown area fed by overhead 23/4.16kV stepdown transformers. Not a saturated area, low stiffness factor test due to high primary amps and low fault duty, impact study would have been required. 23kV system was one conductor span away. Cost of upgrades for 1 span less than the cost of an impact study, so no impact study was required.

Example 296 kW PV Array

Interconnection to a 4.16kV stepdown area

SYSTEM STIFFNESS FACTOR CALCULATION (FED FROM HARWICH #95A LINE, 4kV Stepdown area)

Existing Fault Duty at Point of Interconnection (POI)				
LLL-G	1371	Amperes		
LLL	1281			
LL-G	1187			
LG	1904			
		296 KW PV ARRAY		
		0.296	MW	
Max Isc		1904	Amperes	
Min Isc		1187		
I FL @ 4.16kV		41.1	Amperes	
Stiffness Factor		46.3	(using Max Isc)	(Significant Concern)
(Isc / IFL)		28.9	(using Min Isc)	(Significant Concern)

Short-Circuit Box

LLL	LLG	LL	LG	LG min	
1371	1281	1187	1094	1094	
X1/R1	X0/R0	R1	X1	R0	X0
2.15	2.33	0.7900	1.7004	1.2990	3.0330

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