BEFORE
THE OHIO POWER SITING BOARD

In the Matter of the Letter of Notification Columbus Solar Park LLC Model Landfill Solar 138 kV Gen-Tie Transmission Line Project Franklin County, Ohio.	))))	Case No. No 23-0256-EL-BLN

RESPONSES TO STAFF'S SECOND SET OF DATA REQUESTS
DATED APRIL 27, 2023

---

1. In reference to Columbus Solar Park LLC's ("Solar Park") response to question number 3 of Staff's first set of data requests regarding cost recovery, there would be no expenses or costs allocated to the customers of the City of Columbus or the residents of the city. Is that correct?

   RESPONSE: Correct**.**

2. In reference to Solar Park's response to question number 4 of Staff's first set of data requests, please describe the nature of, the assumptions made, the content of, the results of the "studies" done by the Division of Power ("DOP") that showed no impact to the PJM grid.

   RESPONSE: The relevant studies performed by the City of Columbus were a short circuit study and loadflow study. We include these studies with this response. They detail the assumptions, contents, and results showing our facility will not impact PJM.

3. Did the DOP studies show that the solar facility itself would have no impact to the PJM grid?

   RESPONSE: Yes. The studies show that any impacts from the system would be located solely within the DOP power grid and would not impact the PJM grid.

4. In Solar Park's response to question number 3 of Staff's first set of data requests, Solar Park stated that the "Generator is paying for all the upgrades…". Is the "Generator" referred to in this response BQ Energy, LLC?

   RESPONSE: The Generator is Columbus Solar Park, LLC, a wholly owned subsidiary of BQ Energy Development LLC.

SEL Engineering Services, Inc.

Columbus Interconnection Solar Park - Short Circuit Study Report

GPD Group

20210525

For information regarding this document, contact:

Author..Yan Huang, PE
yan_huang@selinc.com

Reviewer .... Harish Chaluvadi, PE
harish_chaluvadi@selinc.com

Project Manager ....Abdul Rahman
abdul_rahman@selinc.com

SEL ES Project Number 022690.000.00

2350 NE Hopkins Court Pullman, WA 99163-5603 USA Tel: +1.509.332.1890 www.selinc.com

Table of Revisions

Revision Number	Date	Description	Author	Reviewer	Approved
0	20210405	Initial issue	Y. Huang	H. Chaluvadi	
1	20210525	Updated Delta-Wye step-up two winding transformer, Updated the solar system using inverter model	Y. Huang	H. Chaluvadi	

Table of Contents

Figures

Tables

SECTION 1 INTRODUCTION

A new 50 MW solar generation plant is proposed to interconnect to Jackson Pike 138kV substation in Columbus, OH. The developer is BQ Energy LLC.

SEL Engineering Services, Inc. (SEL ES) was contracted by GPD Group to perform a system impact study on the City of Columbus's behalf. This report contains the results of the short-circuit study performed to identify potential adverse system impacts that would result from the interconnection of the proposed facility. The results of a power flow study will be provided as a separate deliverable.

The short-circuit study was performed using the existing system model provided by City of Columbus in CYME 9.0 software.

SECTION 2 REFERENCE INFORMATION

The following supporting documents were used in this study:

[1] Customer provided transmission system model in CYME software "Transmission Fault Study.sxst".

[2] Customer provided solar park data including the site plan and one-line drawings

[3] Power Electronics® inverter model FS3430M short circuit contribution data.

[4] CYME 9.0 software and the reference manual.

[5] "Electrical Transmission and Distribution Reference Book", Copyright 1997 by ABB

SECTION 3 SYSTEM MODEL UPDATE

City of Columbus provided their existing transmission system model in CYME software. Based on the solar system data in [2] and [3], the following equipment have been added into the system model. Appendix A shows the one-line diagram of the updated system model including the transmission system and the proposed interconnect solar system.

1. Fifteen 34.5kV generating units are modeled based on the Power Electronics® inverter information. Each inverter unit has the maximum output power at 3550kVA. A short circuit current output of 61.77A is used per [3]. Figure 3.1 and Figure 3.2 shows the inverter parameters.

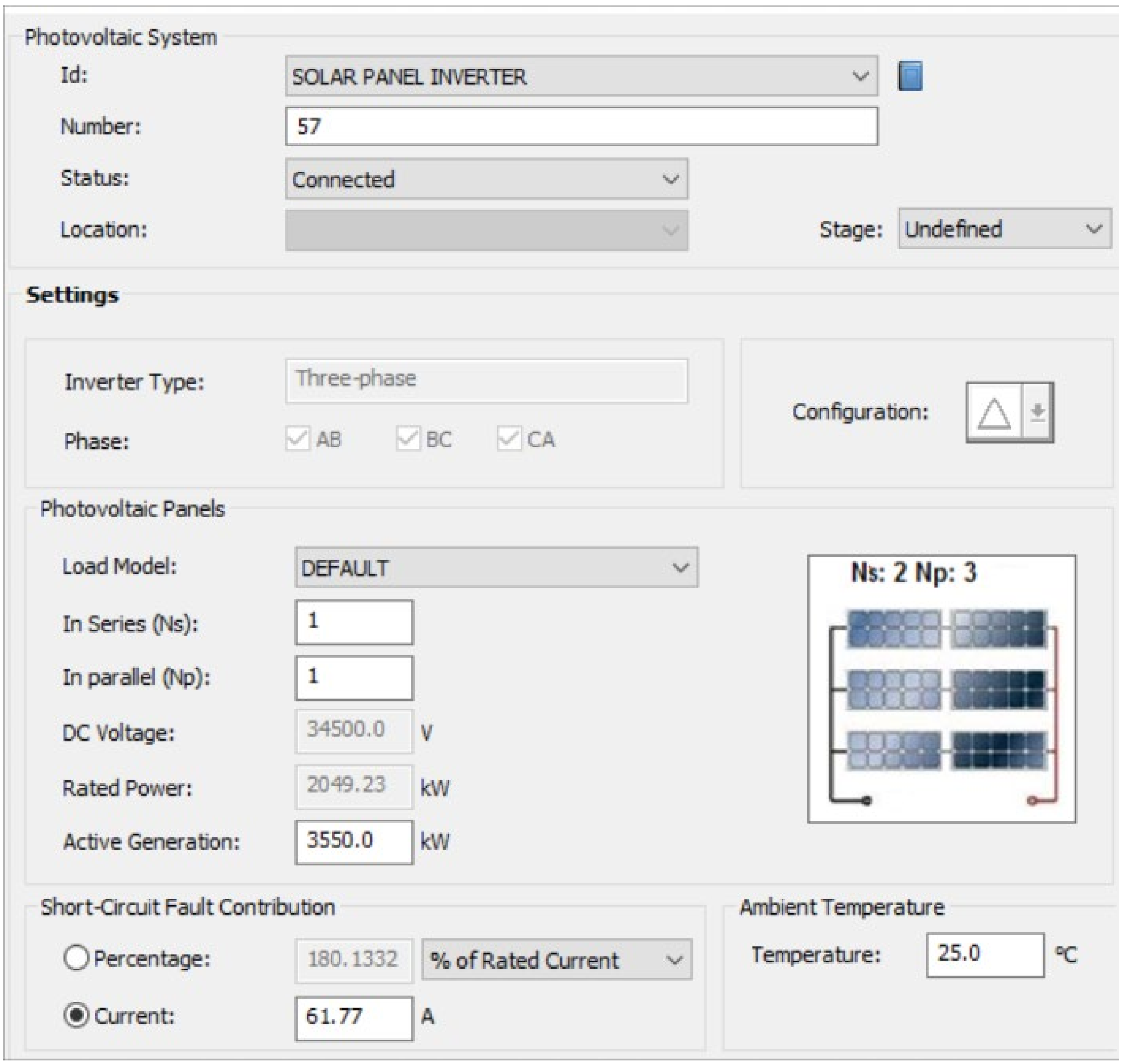


Figure 3.1: Inverter Model Parameters-1

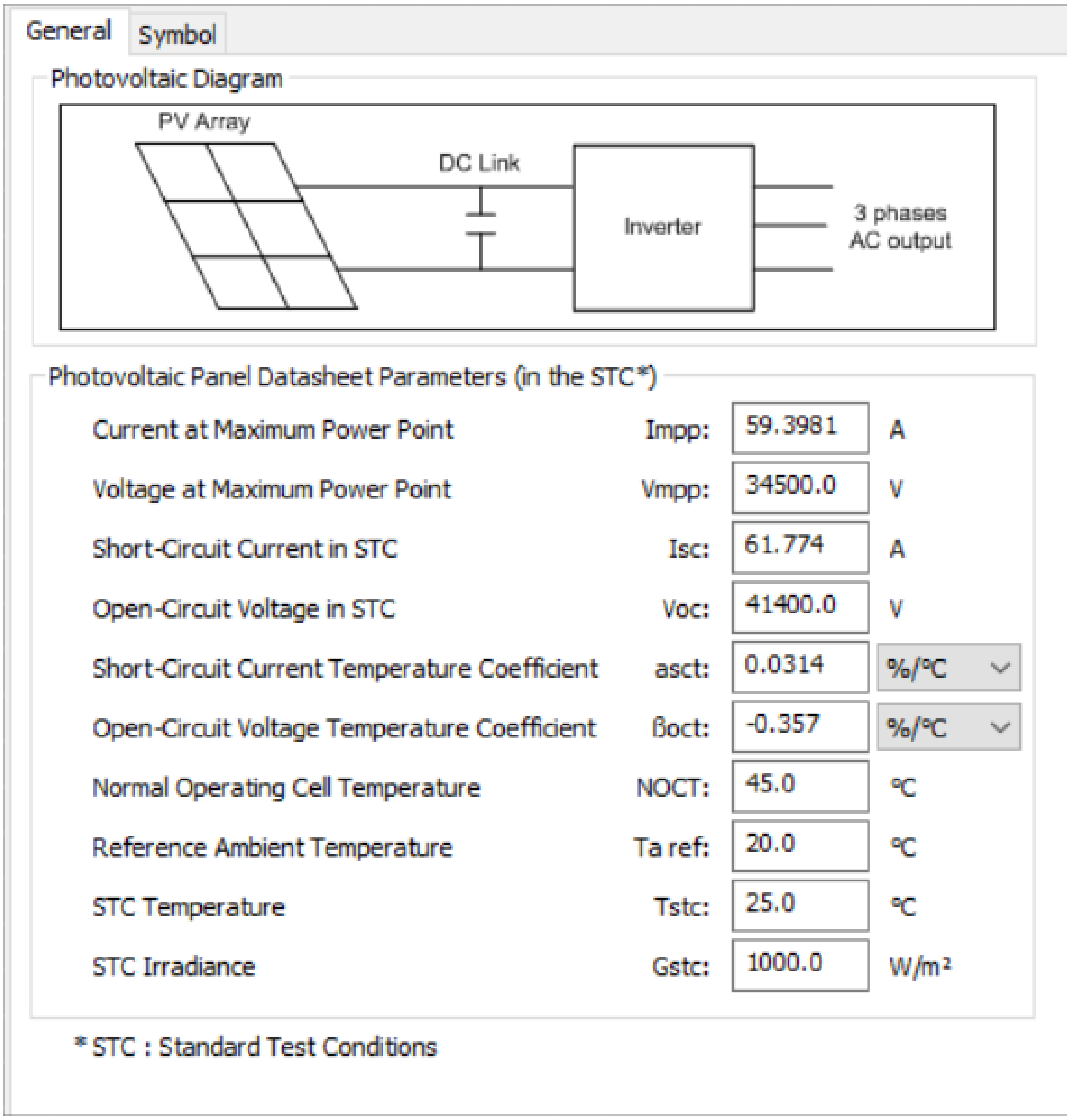


Figure 3.2: Inverter Model Parameters-2

2. A two-winding 138kV/34.5kV Delta-Wye transformer is modeled connecting the Jackson Pike 138kV bus and the 34.5kV solar system. 10% per-unit impedance based on the transformer base rating 34MVA with an X/R ratio of 39 are used per [2]. A screenshot of the one-line drawing CSP_Oneline_R1-Oneline_8_6_2020 is attached in Appendix B.

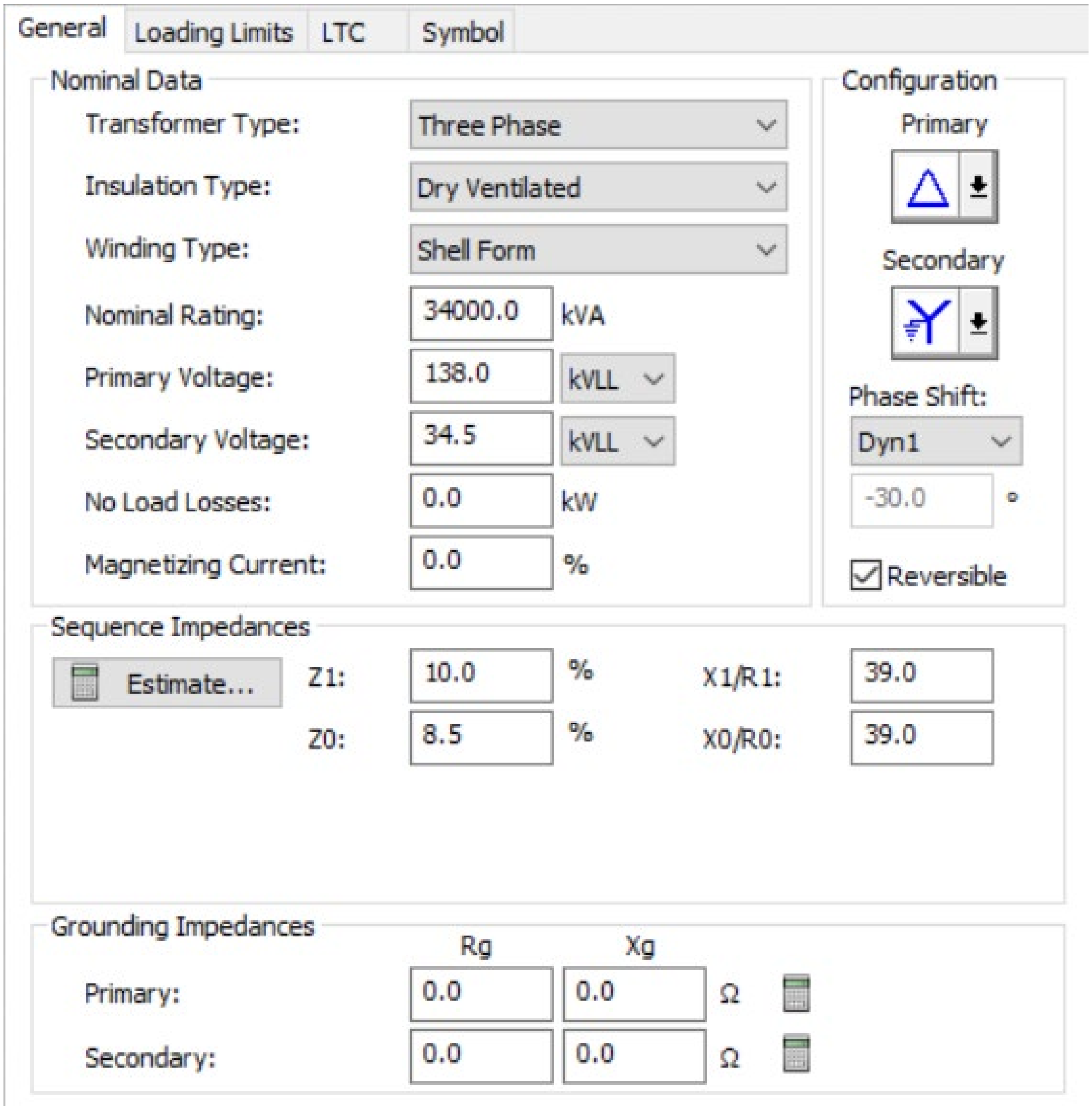


Figure 3.3: Main Step-up Transformer Model Data

SECTION 4 SHORT CIRCUIT STUDY

A short circuit study was conducted using CYME. Per the inverter information provided by the customer, the inverter has a current limit of 1.04 p.u. at 34.5kV based on the maximum output power rating 3550 kVA. The subtransient short circuit current of 61.77A is used in the inverter model.

Each inverter is connected to a Wye-Delta 600V/34.5kV transformer. There is no zero-sequence fault contribution from the inverter to the transmission system. The grounding Wye connected 34.5kV/138kV transformer is the only zero-sequence source of the solar system.

The results of the short circuit study show that the fault currents in interconnection and neighboring substations increase slightly. This is attributed to the small contribution from the solar power plant.

Fault currents near the PV facility computed with and without the new PV facility are summarized in Table 4.1 for three-phase faults.

There is no zero-sequence fault contribution from the inverter or the step-up transformer to the transmission system. The step-up transformer’s delta winding is connected on the transmission side and therefore there is no additional zero-sequence fault current contribution from the new interconnection.

The impedance of the main step-up transformer is the specified value on the customer single line diagram. Transformer manufactory data or test report, when available, will provide more accurate system study results.

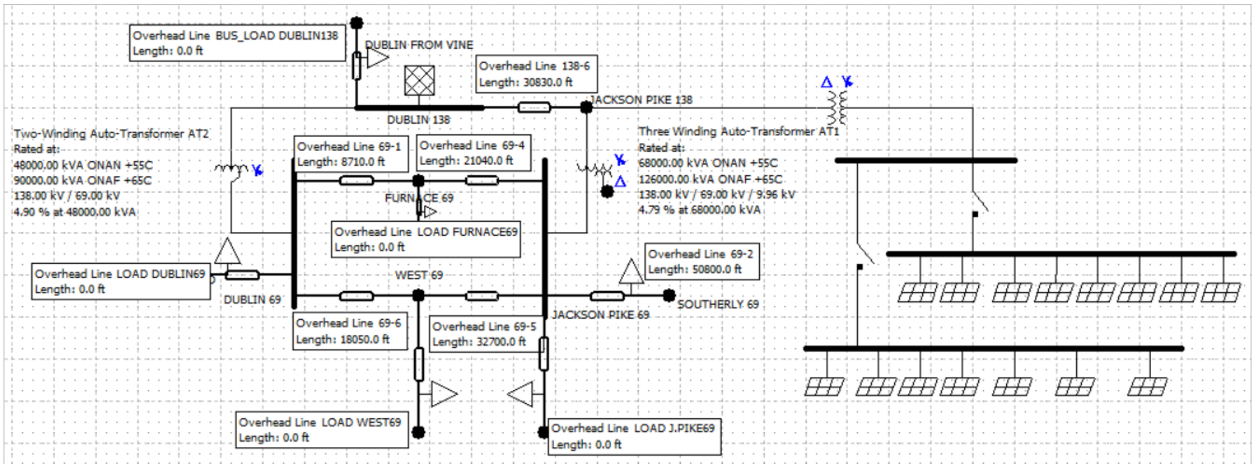
Faulted Bus Name	**Phase Fault Current (Amps)**		
	Base Case	**With Interconnection**	**Increased (%)**
Jackson Pike 138kV	12,439 A	12,635 A	196 A (1.6%)
Dublin 69kV	11,461 A	11,497 A	36 A (0.3%)
West 69kV	8,756 A	8,780 A	24 A (0.3%)
Jackson Pike 69kV	11,789 A	11,844 A	55 A (0.5%)
Furnace 69kV	10,310 A	10,343 A	33 A (0.3%)
Southerly 69kV	3,726 A	3,731 A	5 A (0.1%)
Solar Park 34.5kV (proposed)	NA	6,038 A	NA

Table 4.1: Three-phase Fault Currents at Nearby Buses

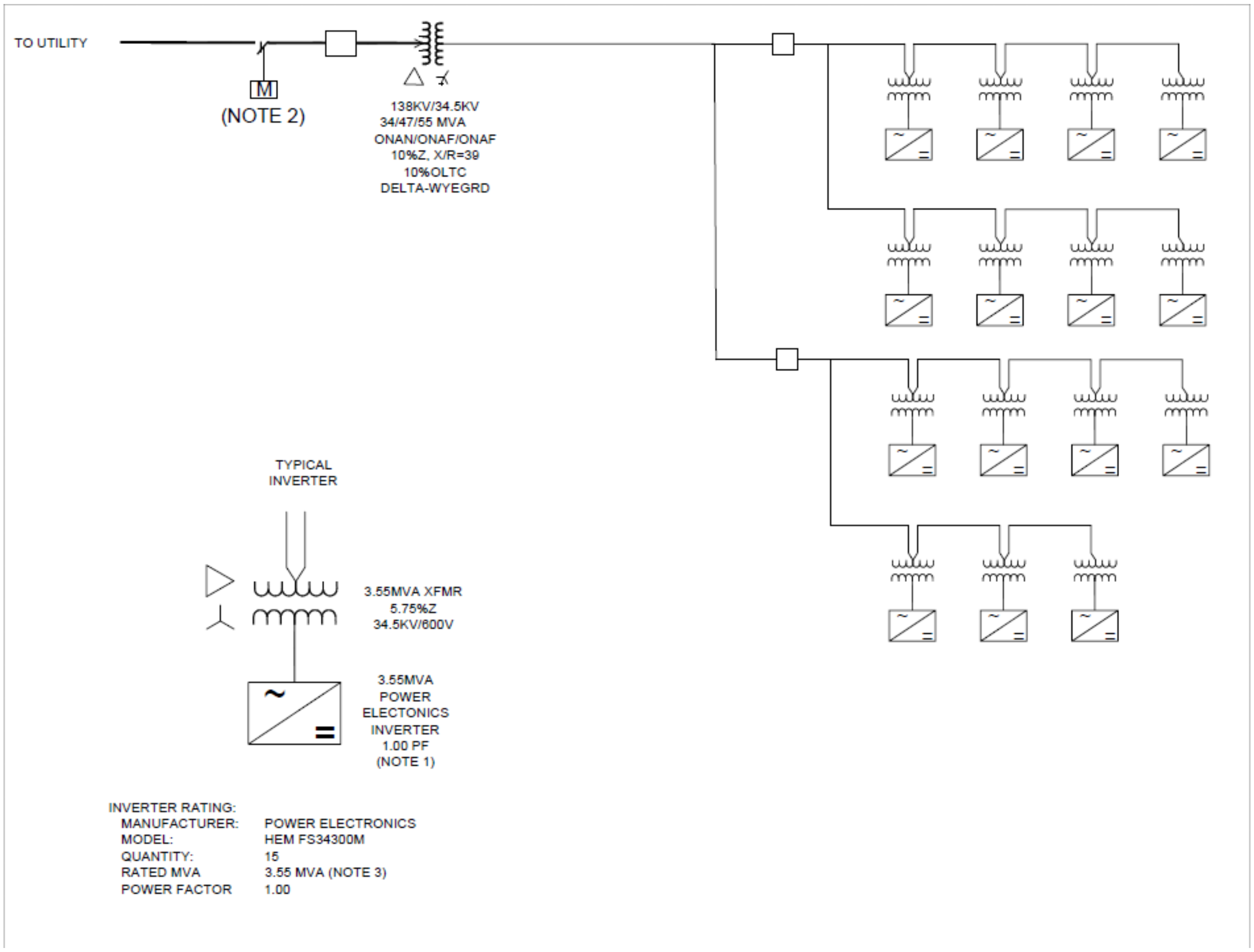
SECTION 5 SUMMARY

The proposed solar system has been modeled and connected to Jackson Pike 138kV substation in the CYME system model. The three-phase faults have been applied on neighboring buses in the transmission system. The short circuit results show a small increase (less than 2%) in the currents at the point of interconnection and nearby substations in the system.

APPENDIX A UPDATED SYSTEM MODEL ONE-LINE



APPENDIX B INTERCONNECTION ONE-LINE DIAGRAM



APPENDIX C INVERTER DATA

Inverter Information

POWER ELECTRONICS
PURE ENERGY

Short Circuit Current Info.

Inverter Series:	HEM
Inverter Output AC Voltage (Vbase):	34500
Inverter Model:	FS3430M

[1] Maximum Output Power (kVA): 3550.00

[2]	Impedance (pu based on unit kVA):	Subtransient:	0.000	+j	0.962		
		Transient:	0.000	+j	1.000		
		Synchronous:	0.000	+j	1.000		
		-ve Sequence:	9999.000	+j	9999.000		
		Zero Sequence:	9999.000	+j	9999.000		
[3]	Short Circuit Current:	First Peak (Ip):	142.400	A	2.397	pu	
		Subtransient (Ik"):	61.774	A(RMS)	1.040	pu	[Duration: < 30ms]
		Transient (Ik'):	59.409	A(RMS)	1.000	pu	
		Synchronous (Ik):	59.409	A(RMS)	1.000	pu	

Short Circuit Datashsheet Revision 08b | 20200630

SEL Engineering Services, Inc.

Columbus Interconnection Solar Park - Load Flow Analysis Report

GPD Group

20210622

For information regarding this document, contact:

Author .... Yan Huang, PE
yan_huang@selinc.com

Reviewer .... Harish Chaluvadi, PE
harish_chaluvadi@selinc.com

Project Manager .... Abdul Rahman
abdul_rahman@selinc.com

SEL ES Project Number 022690.000.00

2350 NE Hopkins Court   Pullman, WA 99163-5603 USA   Tel: +1.509.332.1890   www.selinc.com

Table of Revisions

Revision Number	Date	Description	Author	Reviewer	Approved
0	20210405	Initial issue	Y. Huang	H. Chaluvadi	
1	20210622	Updated Delta-Wye step-up transformer, updated solar system, LTC position	Y. Huang	H. Chaluvadi	

Table of Contents

Figures

Tables

SECTION 1 INTRODUCTION

A new 50 MW solar generation plant is proposed to interconnect to Jackson Pike 138kV substation in Columbus, OH. The developer is BQ Energy LLC.

SEL Engineering Services, Inc. (SEL ES) was contracted by GPD Group to perform a system impact study on the City's behalf. This report contains the results of the power flow analysis performed to identify potential adverse system impacts that would result from the interconnection of the proposed facility.

The power flow was performed using the existing system model provided by City of Columbus in CYME 9.0 software. The customer provided load data has been modeled in the CYME case.

SECTION 2 REFERENCE INFORMATION

The following supporting documents were used in this study:

[1] Customer provided transmission system model in CYME software "Transmission Fault Study.sxst".

[2] Customer provided solar park data including the site plan and one-line drawings.

[3] Customer provided PSSE HEM model data "PE_PSSE_WECC_HEM_R06.pdf".

[4] CYME 9.0 software and the reference manual.

[5] "Electrical Transmission and Distribution Reference Book", Copy right 1997 by ABB

[6] Customer provided system winter and summer load data "Transformer Loading Summary.xlsx".

SECTION 3 SYSTEM MODEL UPDATE

City of Columbus provided their existing transmission system model in CYME software. Based on the solar system data in [2] and [3] and the load date in [6], the following equipment have been added into the system model. Appendix A shows the one-line diagram of the updated system model including the transmission system and the proposed interconnect solar system.

1. Fifteen 34.5kV generating units are modeled based on the Sunpower PV panel inverter information. Each inverter unit has the maximum output power at 3550kVA at 1 p.u. power factor. A subtransient reactance impedance at 0.962 p.u is used for short circuit studies.
   The inverters are operated in voltage control mode. The reactive power capability is modelled with fixed limits of +/-30% of rated active power based on the voltage regulation system (VRS) test results in [3]. Figure 3.1 shows the inverter data.

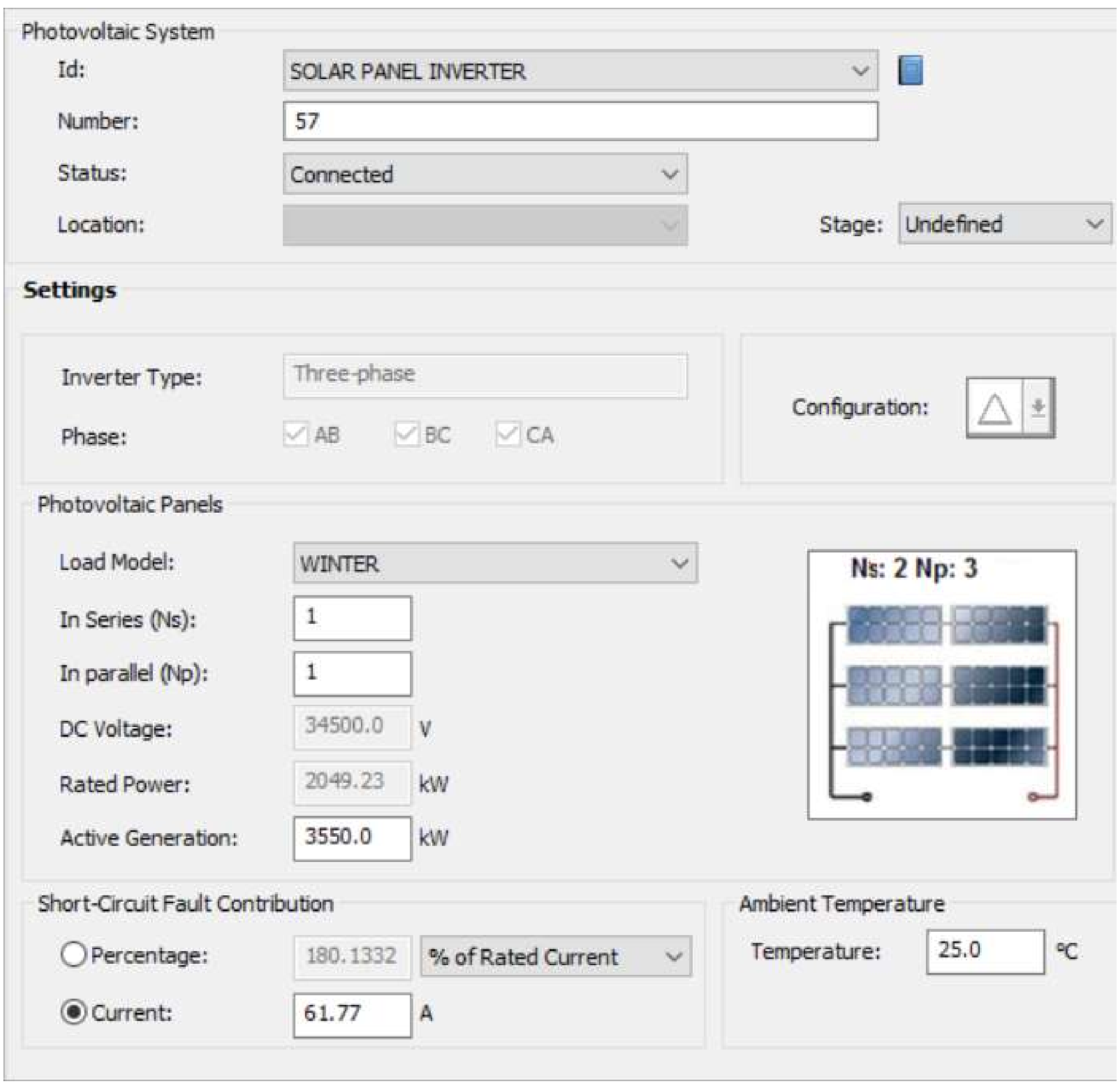


Figure 3.1: Inverter Model Data

2. A two-winding 138kV/34.5kV Delta-Wye transformer is modeled connecting the Jackson Pike 138kV bus and the 34.5kV solar system. 10% per-unit impedance based on the transformer base rating 34MVA with an X/R ratio of 39 are used per [2]. A screenshot of the one-line drawing CSP_Oneline_R1-Oneline_8_6_2020 is attached in Appendix B. The transformer is modelled to have a de-energized load tap changer (DETC) +/-5% regulation and 5 tap steps on the 34.5 kV side, and a load tap changer (LTC) with +/-10% regulation and 32 tap steps (16 in each direction) on the 34.5kV side.

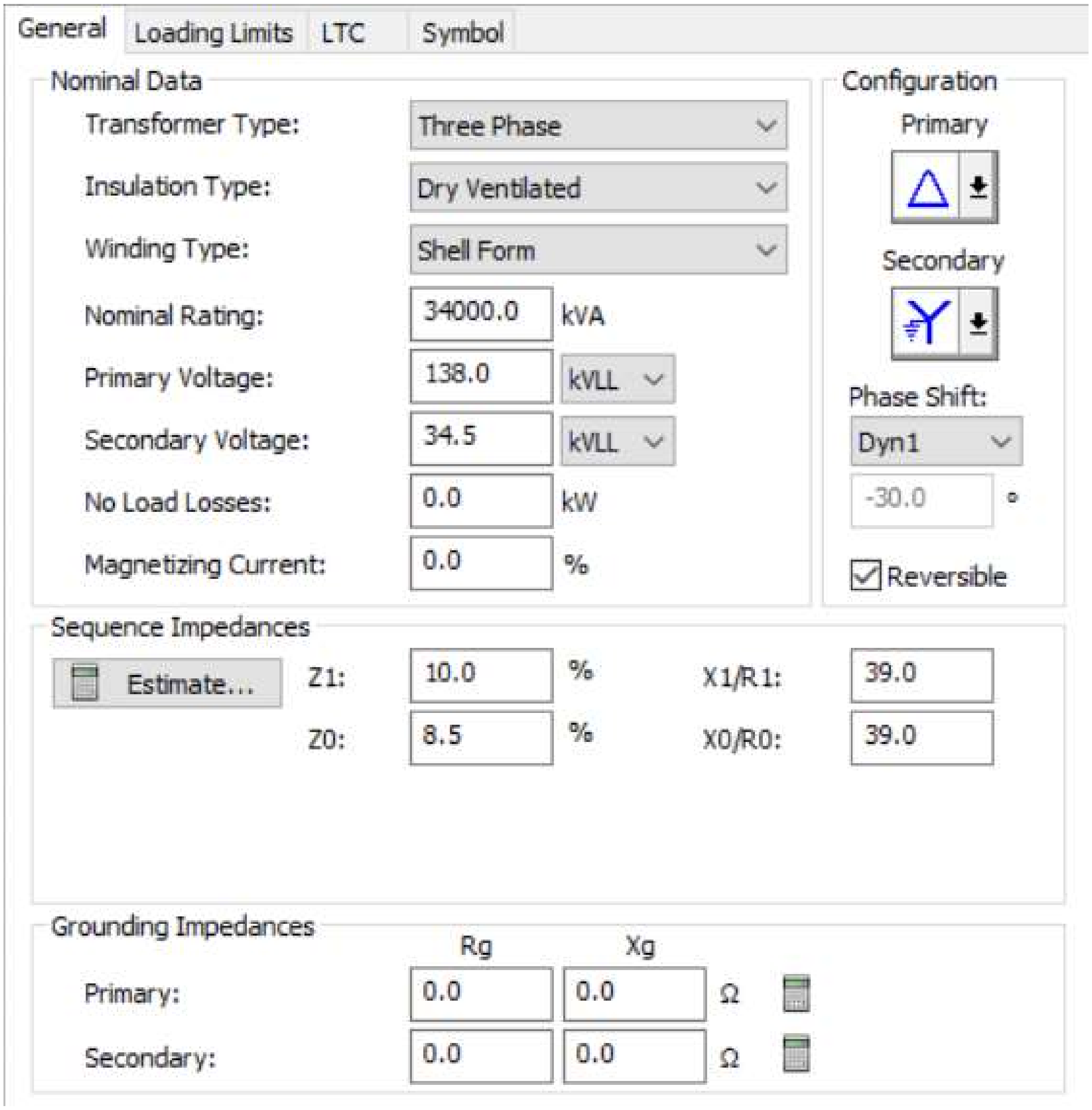


Figure 3.2: Main Step-up Transformer Model Data

3. Based on the system winter and summer average load data in [2], the load sections are added at each substation. The neglectable 0.01 feet connection sections are modeled for the loads. An assumed power factor of 95% is used in the load model. Loads are modeled directly at the transmission/sub-transmission voltage levels for the purpose of this study.

SECTION 4 LOAD FLOW ANALYSIS

The objective of this analysis is to evaluate branch loading effects in the system due to the addition of 49.9 MW of generation connected to the 138 kV Jackson Pike bus in Columbus, OH. In addition, the study will also determine if additional reactive compensation (capacitor) is required at the solar facility, to maintain either the voltage or power factor requirements at the point of interconnect. Finally, the study will identify any adverse effects on the voltage profile of the transmission system due to the addition of the solar facility.

For this study we assume the point of interconnect is the 34.5kV bus and the bus voltage is desired to be maintained at 1.0pu and power factor close to 100%.

Dublin AT2 transformer's de-energized tap changer on the high side is set at 97.5% in the model to match the field conditions. Jackson Pike AT1 transformer's de-energized tap changer is set at 95%. Based on the customer's metering data, the Dublin 138kV AEP source is operated at 1.05pu of nominal 138kV (or 145kV).

The present analysis is based upon the power flow case that represents projected heavy loading during the winter and the summer provided by the customer. The load flow study is to analyze the steady-state performance of the power system. Analysis was conducted to see the impact on system voltages and transmission line thermal ratings for N-1 contingencies. Transmission voltage criteria of 0.95 p.u. to 1.05 p.u. was applied for both base and contingency conditions. Appendix D shows the load flow data for transformers, lines, and buses during normal, N-1, and select N-2 system configurations.

Power flow cases considered are as follows:

1. Normal winter base case
2. Normal summer base case
3. N-1 winter base case when 138kV/69kV Dublin T2 transformer out
4. N-1 summer base case when 138kV/69kV Dublin T2 transformer out
5. N-1 winter base case when 138kV/69kV Jackson Pike T1 transformer out
6. N-1 summer base case when 138kV/69kV Jackson Pike T1 transformer out
7. N-1 winter base case when Dublin – Furnace 69kV line out
8. N-1 summer base case when Dublin – Furnace 69kV line out
9. N-1 winter base case when Dublin – West 69kV line out
10. N-1 summer base case when Dublin – West 69kV line out
11. N-1 winter base case when Jackson Pike – Furnace 69kV line out
12. N-1 summer base case when Jackson Pike – Furnace 69kV line out
13. N-1 winter base case when Jackson Pike – West 69kV line out
14. N-1 summer base case when Jackson Pike – West 69kV line out
15. N-1 winter base case when Jackson Pike – Southerly 69kV line out

16. N-1 summer base case when Jackson Pike – Southerly 69kV line out
17. N-1 winter base case when Dublin – Jackson Pike 138kV line out
18. N-1 summer base case when Dublin – Jackson Pike 138kV line out
19. N-2 winter case when Dublin – West 69kV & Dublin - Furnace 69kV lines out
20. N-2 summer case when Dublin – West 69kV & Dublin - Furnace 69kV lines out
21. N-2 winter case when Dublin – Jackson Pike 138kV & Dublin - Furnace 69kV lines out
22. N-2 summer case when Dublin – Jackson Pike 138kV & Dublin - Furnace 69kV lines out

SECTION 5 SUMMARY

Power flow simulations were conducted for selected outages on both the existing system, and the system with the solar system connected to Jackson Pike Substation. The results indicated that the interconnection of the 49.9 MW plant at either location does not cause any thermal overloads of transmission lines and transformers in the transmission system for the contingencies studied. Results also show that operating the inverters in the voltage control mode and employing an LTC on the step up transformer are adequate for maintaining unity power factor and 1.0pu voltage at the 34.5kV bus. This assumes that the inverters have +/-30% of nameplate power rating in terms of reactive power output.

When the simulations are run, the LTC on the solar farm step up transformer operates between -5 to -8 depending on the loading and the system configuration. In order to operate at a tap closer to the neutral, the DETC can be connected to the +2.5% tap (141.5/34.5 nominal). This will operate the LTC between 0 and 3.

The transformer models at Dublin AT2 and Jackson Pike AT1 in the customer provided CYME model appear to have an LTC on the low side and they operate at a high tap position (-13) to regulate the low side bus voltage to 1.0 pu since the transmission voltage is higher than nominal. Customer should validate these results. Nevertheless, they do not have a significant impact on the transmission voltages and do not impact the conclusions of the study, which is pertaining to the solar project recommendations.

Voltage criteria of 0.95 p.u. to 1.05 p.u. was not violated for any of the transmission buses in the 69kV lines contingencies evaluated. For the N-1 conditions where the Dublin 138kV/69kV transformer is out of service or the Jackson 138kV/69kV transformer is out of service, voltage is below 0.95 p.u. for both the existing system and the solar system connected. Table 5.1 shows the simulation cases, the bus voltage and equipment overload conditions.

Case	System Condition	Bus Voltage (0.95-1.05 p.u.)		Equipment Overload	
		Existing System	With Solar Generation	Existing System	With Solar Generation
1	Normal winter base case	OK	OK	OK	OK
2	Normal summer base case	OK	OK	OK	OK
3	N-1 winter base case when 138kV/69kV Dublin T2 transformer out	OK	OK	OK	OK
4	N-1 summer base case when 138kV/69kV Dublin T2 transformer out	OK	OK	OK	OK
5	N-1 winter base case when 138kV/69kV Jackson Pike T1 transformer out	OK	OK	OK	OK
6	N-1 summer base case when 138kV/69kV Jackson Pike T1 transformer out	OK	OK	OK	OK

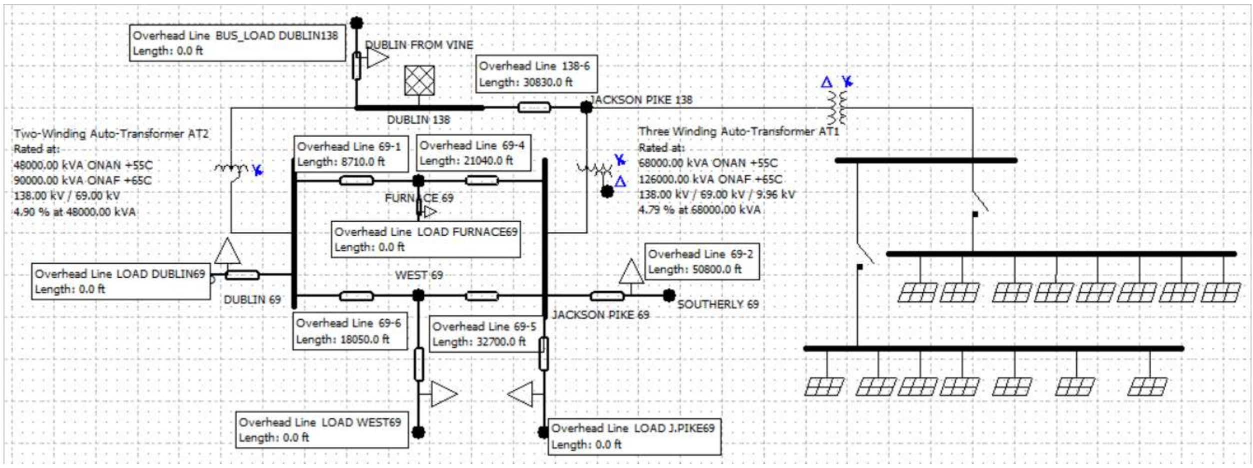
Case	System Condition	Bus Voltage (0.95-1.05 p.u.)		Equipment Overload	
		Existing System	With Solar Generation	Existing System	With Solar Generation
7	N-1 winter base case when Dublin – Furnace 69kV line out	OK	OK	OK	OK
8	N-1 summer base case when Dublin – Furnace 69kV line out	OK	OK	OK	OK
9	N-1 winter base case when Dublin – West 69kV line out	OK	OK	OK	OK
10	N-1 summer base case when Dublin – West 69kV line out	OK	OK	OK	OK
11	N-1 winter base case when Jackson Pike – Furnace 69kV line out	OK	OK	OK	OK
12	N-1 summer base case when Jackson Pike – Furnace 69kV line out	OK	OK	OK	OK
13	N-1 winter base case when Jackson Pike – West 69kV line out	OK	OK	OK	OK
14	N-1 summer base case when Jackson Pike – West 69kV line out	OK	OK	OK	OK
15	N-1 winter base case when Jackson Pike – Southerly 69kV line out	OK	OK	OK	OK
16	N-1 summer base case when Jackson Pike – Southerly 69kV line out	OK	OK	OK	OK
17 (Note 1)	N-1 winter base case when Dublin – Jackson Pike 138kV line out	Lowest 0.854 p.u	Lowest 0.837 p.u	141.7%	94.6%
18 (Note 1)	N-1 summer base case when Dublin – Jackson Pike 138kV line out	Lowest 0.853 p.u	Lowest 0.837 p.u	158.1%	109.8%
19	N-2 winter case when Dublin – West 69kV & Dublin - Furnace 69kV lines out	OK	OK	OK	OK
20	N-2 summer case when Dublin – West 69kV & Dublin - Furnace 69kV lines out	OK	OK	OK	OK
21 (Note 2)	N-2 winter case when Dublin – Jackson Pike 138kV & Dublin - Furnace 69kV lines out	Lowest 0.799 p.u	Lowest 0.779 p.u	148.7%	101.4%
22 (Note 2)	N-2 summer case when Dublin – Jackson Pike 138kV & Dublin - Furnace 69kV lines out	Lowest 0.794 p.u	Lowest 0.777 p.u	167%	118.1%

Table 5.1: Bus Voltage and Equipment Overload

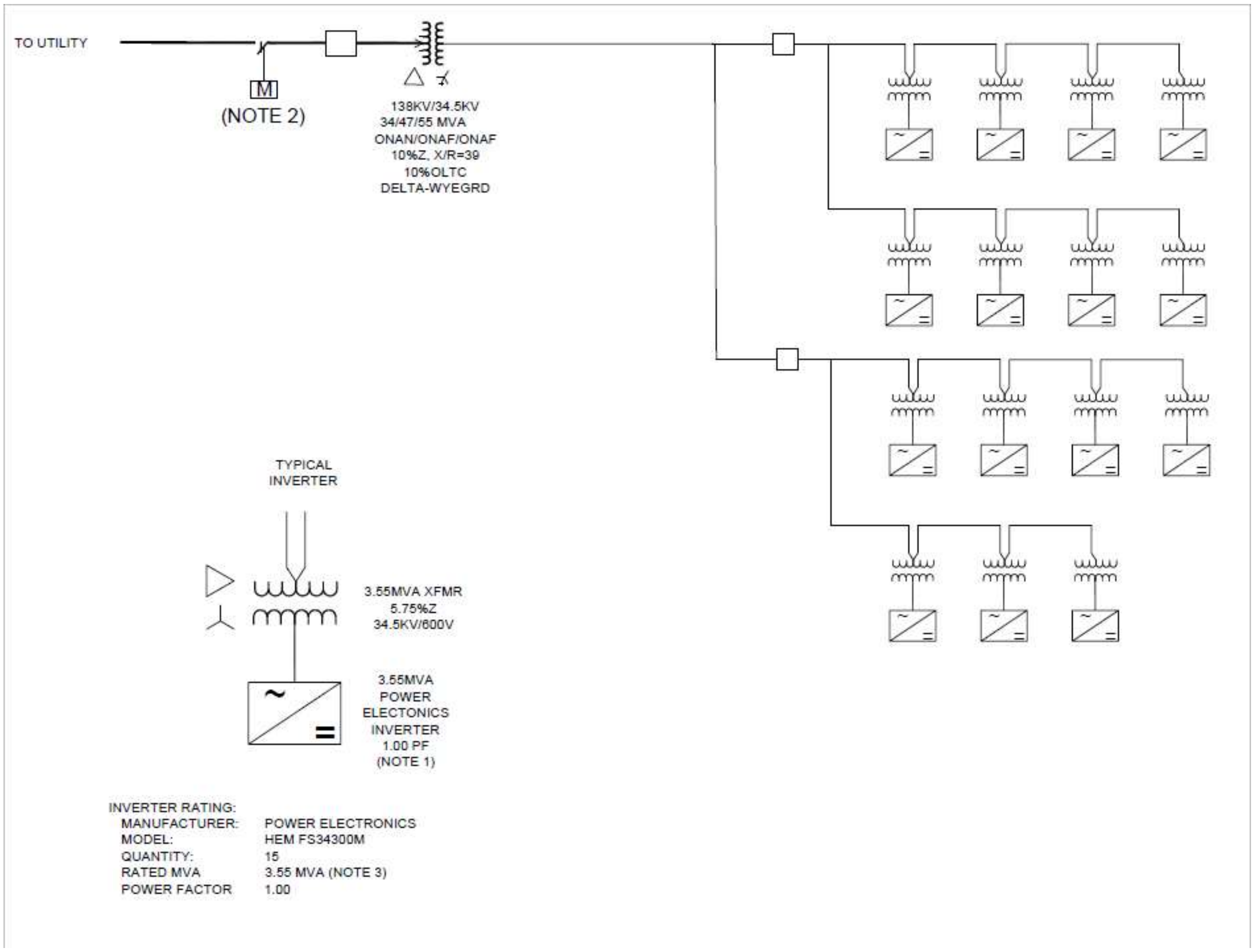
Note 1: For Case 17 and Case 18 when Dublin – Jackson Pike 138kV line is out of service, the Jackson Pike high side bus voltage is below 0.95 p.u. of nominal voltage.

Note 2: For Case 21 and Case 22 when Dublin – Jackson Pike 138kV and Dublin – Furnace 69kV lines are out of service, the Jackson Pike high side, low side, Furnace 69kV, and Southerly 69kV bus voltages are below 0.95 p.u. of nominal voltage.

APPENDIX A UPDATED SYSTEM MODEL-ONE LINE



APPENDIX B INTERCONNECTION ONE-LINE DIAGRAM



APPENDIX C INVERTER DATA

Inverter Information

POWER ELECTRONICS PURE ENERGY

Short Circuit Current Info.

Inverter Series:	HEM
Inverter Output AC Voltage (Vbase):	34500
Inverter Model:	FS3430M

[1] Maximum Output Power (kVA): 3550.00

[2] Impedance (pu based on unit kVA):

Subtransient:	0.000	+j	0.962
Transient:	0.000	+j	1.000
Synchronous:	0.000	+j	1.000
-ve Sequence:	9999.000	+j	9999.000
Zero Sequence:	9999.000	+j	9999.000

[3] Short Circuit Current:

First Peak (Ip):	142.400	A	2.397	pu	
Subtransient (Ik"):	61.774	A(RMS)	1.040	pu	[Duration: < 30ms]
Transient (Ik'):	59.409	A(RMS)	1.000	pu	
Synchronous (Ik):	59.409	A(RMS)	1.000	pu	

Short Circuit Datashsheet Revision 08b | 20200630

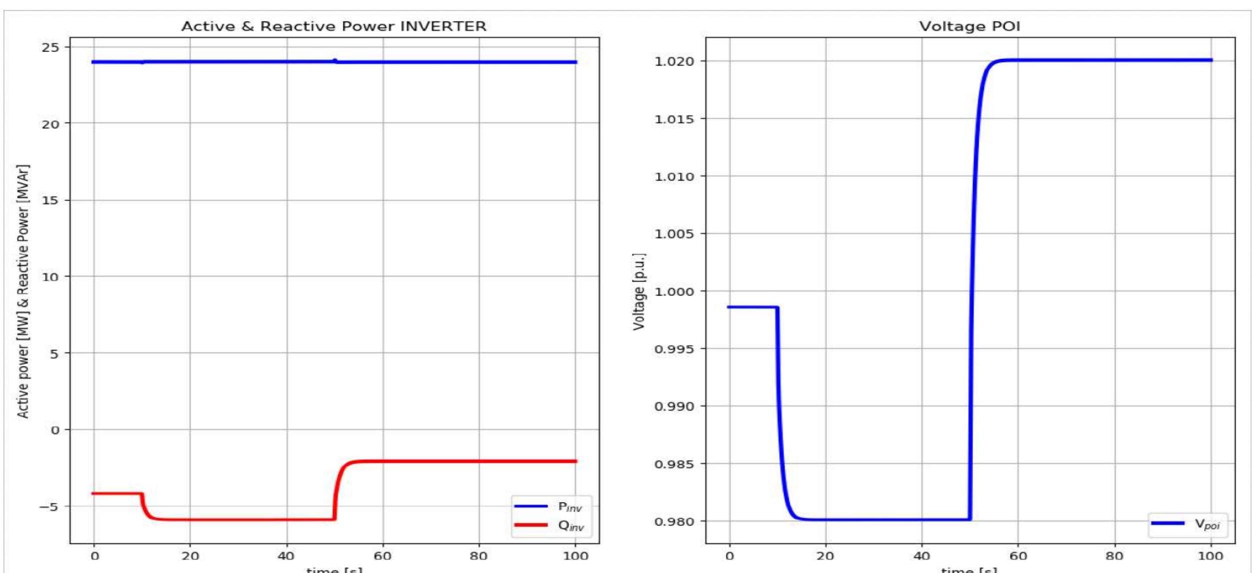


FIGURE 6. VRS RESULTS

APPENDIX D LOAD FLOW DATA