University of Idaho Microgrid Expansion

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Executive Summary

The University of Idaho seeks to ultimately have the capability of self-sustaining its energy demands upon an emergency Avista outage. The "Take a Load Off" team of which this project is building from constructed a load shedding scheme based on the 825 kW of power coming from the Steam Plant and the full loads of the following buildings in prioritized order: McClure, CNR, BEL, and GJL.

This microgrid expansion project looks at the integration of several new generation sources: a 1 MW backup solar array, a 140kW solar array on top of the IRIC building, and backup generators within McClure, CNR, BEL, and GJL. Also, the design focuses on the emergency 480V circuits of the existing buildings and adds the loads of the Steam Plant and the IRIC emergency circuits. The study also serves to assess how much additional load may be supported from available generation during different use cases.

The worst-case scenario is if Avista goes down during summertime at night and both wells on campus need to be ran at the same time to support suppression in the event of a fire. The PowerWorld model which was used to simulate the expansion reveals that the generation from the Steam Plant and backup generators within buildings can be diverted to support the wells. Backup generators will need to be synchronized to the grid for this to work. This is discussed in more detail within the report.

Under a less severe use case where the Wells need not be supported, the backup generators within McClure, BEL, and GJL are able to support their own emergency circuits islanded from the grid. The IRIC has this same capability, but instead using its solar array. If there is not enough sunlight, it can also use its designated backup generator. Excess generation from the Steam Plant and Solar Backup Array in this case may be used to support additional emergency circuits within buildings on campus that may not have backup generators or may be used in lieu of running the backup generators in an effort to be more environmentally conscious.

Most of what has been explained regarding the use cases is based on the results of the Power Flow analysis conducted within PowerWorld. Other analyses performed reveal pertinent data and give insight into the functionality and operability of the Microgrid. These analyses include: N-1 Contingency, Seasonal, Fault, and Load Shedding.

PowerWorld automatically indicates the best locations for remote breakers and can be seen and toggled within the simulation. It has been assessed that six more SEL 751 relays and an RTAC are required for the expansion, with more 751 relays needed as it grows further. Topics such as further expansion, energy storage, black start, and integrating the load shedding scheme developed by the "Take a Load off" team are recommended for upcoming projects.

Background

The overall UI microgrid scope includes the entire campus, with a total of 143 buildings, excluding Northern farms. Currently, 12% of the campus load is expected to be provided by the new Steam Plant turbines, of which 3% must provide electricity for the Steam Plant. The turbines are expected to be placed in service by Fall 2020. The remaining 9% of annual power production was allocated for the "Take a Load Off" project. Their project scope included designing the load shed algorithm for the following campus buildings: McClure, CNR, GJL, BEL. The microgrid generation considered for their project included the steam turbines in the Steam Plant and solar panels to be placed on the roof of IRIC. They designed a module load shed scheme that can be scaled when more generation sources are determined for the UI microgrid.

Our project now takes into account the new generation source of the one-megawatt solar array that has been proposed by the "SPBG" team to be in Lot 57 next to the Kibbie Dome with the purpose of supplying power to the well pumps out near Winco. When the load of the wells is not being demanded, the array can then be used to support additional critical emergency circuits within buildings on campus. Our design also incorporates the use of emergency backup generators within buildings to support their emergency circuits.

Problem Definition

With the addition of the one-megawatt solar array, critical loads on campus are to be assessed and how much of campus could be supported by the new array shall be revealed. Also, the type and location of equipment needed to expand the microgrid (switches, relays, etc.) need to be determined. In addition, the microgrid performance must be analyzed with the different energy sources, seasonal changes in total system capacity must be accounted for, and an economic analysis conducted.

Microgrid Simulation Design

The decision was made to use the PowerWorld simulation software as opposed to the RTDS simulation software that the previous team used. The reasoning for this is because whiel RTDS is great for conducting real time testing of the RTAC controls and relays, PowerWorld reigns superior in overall grid analysis. PowerWorld is robust and versatile and allows us to dive deeper into revealing the effects associated with how this grid will and will not work. The simulation is also modular and can be easily added to when it comes time for future teams to expand the micro-grid even further.

Power Flow Analysis (Worse Case Scenario)

Our design is based on a best case and a worst-case scenario. Figure 1 shows the worst-case scenario.



Figure 1: Power Flow Worst Case Scenario

In the worst-case scenario, all necessary generation must go to power both wells running at 700kW. Here we can see that at rated power the one mega-watt array is sufficient to supply both the real and reactive demands of the wells. Each critical emergency circuit within the buildings is supported by its own backup generator. After meeting its own load demand, the Steam Plant is still able to supply 645kW of power to additional load on campus. Under the circumstances of the backup array being insufficient due to lack of sunlight or other failure, load can be shed and power from the Steam Plant, backup generators, and the IRIC solar array can be harnessed to support the full loads of the wells.



Power Flow Analysis (Best Case Scenario)

Figure 2: Power Flow Best Case Scenario

In the best-case scenario, the well pumps are not running and do not need to be supported. This frees up the one mega-watt solar array power to now support a substantial amount of load on campus. Now, between the array and the excess steam turbine generation, an additional 1.645 mega-watts of excess power is available. Both power flow analyses were done under the assumption of rated equipment values and a 0.9 lagging power factor for building loads.

Seasonal Analysis

For the seasonal analysis, we used data given to us by Facilities and the Solar Backup Generation team to simulate power flow analysis at each month, starting in January. The seasonal analyses were done at normal operating conditions, with the microgrid islanded from the power grid. The monthly data from the Steam Plant is using future planned additions. Based on our location, solar generation will be best in the summer months and worst in the winter months and the opposite being true for the Steam Plant, being best in the winter months and worst in the summer months. In the appendix, there are instructions on how to change Powerworld to certain months so that you may view and simulate different scenarios.

After conducting a power flow analysis of each month, we calculated the following data shown in graphs. The following graph showcases the total load consumption and generation for the entire microgrid design. This includes the backup generators, the noncritical loads, and the losses of transmission lines and transformers. The total consumption is from the noncritical and critical loads currently included in the microgrid design as well as the losses due to the transmission and transformers calculated by Powerworld. As seen in the graph, we will have excess generation while islanded from the grid and in the best-case scenario.



The following graph shows all the different sources of generation and loads that we deemed important and critical. Using the data, the following graph was created that showcases the monthly changes. The graphs following show the loads and generation separate to have a more detailed look.



Since the wells do not normally take much power to operate, there will be excess generation during all months of the year. When both wells need power is when issues will start to occur, and load shedding will need to be implemented.



The monthly generation values showcase that the steam plant will be the main source of generation. Since the backup generators do not change depending on the month or season, they were not included on this graph. The excess generation shown in the above graph is calculated from the total consumption and total generation from the entire microgrid design in a best-case scenario.



Fault Analysis

Solar Backup Array – Bus Fault – Single Line-to-Ground:

Bus Records:

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	0.22180	0.79696	0.94349	-76.98	-126.69	64.61
2	2	Array-Microgrid,	0.38773	0.99476	0.64654	38.34	-121.02	71.19
3	3	Wells transform	0.35515	0.91118	0.59222	41.11	-118.24	73.96
4	4	Wells	0.35299	0.90563	0.58861	40.63	-118.73	73.48
5	5	Campus 13.2kV	0.99684	0.99684	0.99684	-0.37	-120.37	119.63
6	6	Steam Plant	1.00000	1.00000	1.00000	-30.00	-150.00	90.00
7	7	CNR XFMR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
8	8	CNR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
9	9	CNR BG	1.00000	1.00000	1.00000	-30.05	-150.05	89.95
10	10	IRIC XFMR	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
11	11	IRIC	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
12	12	GJL XFMR	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
13	13	GJL	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
14	14	GJL BG	1.00000	1.00000	1.00000	29.34	-90.66	149.34
15	15	BEL XEMR	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
16	16	BEL	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
17	17	BEL BG	1.00000	1.00000	1.00000	29.32	-90.68	149.32
18	18	MCCLURE XFMR	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
19	19	MCCLURE	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
20	20	MCCLURE BG	1.00000	1.00000	1.00000	-30.60	-150.60	89.40

Lines:

	From	From Name	To Number	To Name	Circuit	Xfrme	Phase Cur A From	Phase Cur B From	Phase Cur C From	Phase Cur A To	Phase Cur B To	Phase Cur C To
1	1	SOLAR BAC	2	Array-Micro	1	YES	23902.85	40467.34	59609.71	445315.84	1142519.25	742582.06
2	2	Array-Micro	3	Wells trans	1	NO	445319.53	1142520.38	742579.25	16193.44	41546.20	27002.88
- 4	3	Wells trans	4	Wells	1	YES	16193.47	41546.27	27002.98	89064.05	228504.44	148516.38
5	6	Steam Plan	5	Campus 13	1	YES	864741.56	864741.50	864741.50	31445.10	31445.10	31445.10
26	1 1	Campus 13		CNR XFMR	1	NO						
17	5	Campus 13				NO						
- 1	5	Campus 13			1	NO						
		Camput 13		MCCLURES		NO						
10	8	CNR	7	CNR XFMR	1	VES	0.00	0.00	0.00	0.00	0.00	0.00
11	1.17					NO						
12	9	CNR BG	8	CNR	1	YES	1300255.50	1300255.50	1300255.50	750354.44	750354.44	750354.44
13	11	IRIC	10	IRIC XFMR	1	YES	0.02	0.02	0.02	0.00	0.00	0.00
14	12	GJL XFMR	13	GJL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
15	13	GJL	14	GJL BG	1	YES	26896.67	26896.67	26896.67	46610.46	46610.46	45610.46
16	15	BEL XEMR	16	BEL	1	VES	0.00	0.00	0.00	0.00	0.00	0.00
17	16	BEL	17	BEL BG	1	YES	46809.79	46809.79	46809.78	81116.88	81116.88	81116.88
18	19	MCCLURE	18	MCCLURE >	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
19	20	MCCLURE B	19	MCCLURE	1	YES	293855.16	293855.16	293855.16	169577.42	169577.42	169577.41

Generators:

	Number of Bus	Name of Bus	Phase Cur A	Phase Cur B	Phase Cur C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	73090.05	40467.26	59609.73	-85.88	149.80	59.95
2	6	Steam Plant	1105204.85	1105204.97	1105204.85	-56.12	-176.12	63.88
3	9	CNR BG	1300250.20	1300250.30	1300250.20	-56.20	-176.20	63.80
4	11	IRIC	187206.57	187206.57	187206.58	-27.09	-147.09	92.91
5	14	GJL BG	46610.98	46610.99	46610.98	2.77	-117.23	122.77
6	17	BEL BG	81114.11	81114.11	81114.11	3.39	-116.61	123.39
7	20	MCCLURE BG	293848.04	293848.07	293848.04	-58.14	-178.14	61.86

	Number of Bus	Name of Bus	ID	Phase Cur A	Phase Cur B	Phase Cur C
1	4	Wells	1	89063.91851	228504.14336	148515.93549
2	5	Campus 13.2kV	1	31445.10622	31445.10622	31445.10622
3	6	Steam Plant	1	240469.37330	240469.37330	240469.37330
4	8	CNR	1	750352.76275	750352.76275	750352.76275
5	11	IRIC	1	187206.55320	187206.55320	187206.55320
6	13	GJL	1	26898.40825	26898.40825	26898.40825
7	16	BEL	1	46809.60342	46809.60342	46809.60342
8	19	MCCLURE	1	169574.81793	169574.81793	169574.81793

Solar Backup Array – Bus Fault – Line-to-Line:

Bus Records:

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	1.00000	0.55856	0.44516	-30.57	153.84	143.90
2	2	Array-Microgrid,	0.89451	0.08188	0.82917	-29.44	-173.99	147.28
3	3	Wells transform	0.81936	0.07500	0.75950	-26.66	-171.22	150.05
4	4	Wells	0.81436	0.07455	0.75487	-27.15	-171.70	149.57
5	5	Campus 13.2kV	0.99684	0.99684	0.99684	-0.37	-120.37	119.63
6	6	Steam Plant	1.00000	1.00000	1.00000	-30.00	-150.00	90.00
7	7	CNR XFMR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
8	8	CNR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
9	9	CNR BG	1.00000	1.00000	1.00000	-30.05	-150.05	89.95
10	10	IRIC XEMR	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
11	11	IRIC	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
12	12	GJL XFMR	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
13	13	GJL	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
14	14	GJL BG	1.00000	1.00000	1.00000	29.34	-90.66	149.34
15	15	BEL XFMR	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
16	16	BEL	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
17	17	BEL BG	1.00000	1.00000	1.00000	29.32	-90.68	149.32
18	18	MCCLURE XFMR	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
19	19	MCCLURE	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
20	20	MCCLURE BG	1.00000	1.00000	1.00000	-30.60	-150.60	89.40

Lines:

	From Number	From Name	To Numbe	r To Name	Circuit	Xfrmr	Phase Cur A From	Phase Cur B From	Phase Cur C From	Phase Cur A To	Phase Cur B To	Phase Cur C To
10001	1	SOLAR BAC	2	Array-Micro	1	YES	41546.28	23206.23	18494.85	1027383.25	94043.54	952332.13
2	2	Array-Micro	3	Wells trans	1	NO	1027382.56	94044.23	952332.50	37359.37	3419.79	34630.27
1 0	1 1	Array-Micro			1							
4	3	Wells trans	4	Wells	1	YES	37359.52	3419.86	34630.34	205477.38	18809.22	190466.88
5	6	Steam Plan	5	Campus 13	1	YES	864741.56	864741.50	864741.50	31445.10	31445.10	31445.10
1				CHIR XFMR	1	NO						
0-7	- 5				1	NO						
	1.1.1				1	NO						
0.00	1 1			MCCUURE >	1	NO						
10	8	CNR	7	CNR XFMR	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
S 01	1.1					NO						
12	9	CNR BG	5	CNR	1	YES	1300255.50	1300255.50	1300255.50	750354.44	750354.44	750354.44
13	11	IRIC	10	IRIC XEMR	1	VES	0.02	0.02	0.02	0.00	0.00	0.00
14	12	GJL XFMR	13	GIL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
15	13	GJL	14	GJL BG	1	YES	26896.67	26896.67	26896.67	46610.46	46610.46	46610.46
16	15	BEL XEMR	16	5 BEL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
17	16	BEL	17	BEL BG	1	YES	46809.79	46809.79	46809.78	81116.88	81116.88	81116.88
18	19	MCCLURE	18	MCCLURE >	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
19	20	MCCLURE E	19	MCCLURE	1	YES	293855.16	293855.16	293855.16	169577.42	169577.42	169577.41

Generators:

	Number of Bus Nam	e of Bus	Phase Cur A	Phase Cur B	Phase Cur C	Phase Ang A	Phase Ang B	Phase Ang C
1	1 SOLA	RBACKUP	41546.21	76169.82	58548.72	-64.27	165.36	18.08
2	6 Steam	Plant	1105204.85	1105204.97	1105204.85	-56.12	-176.12	63.88
3	9 CNR E	G	1300250.20	1300250.30	1300250.20	-56.20	-176.20	63.80
4	11 IRIC		187206.57	187206.57	187206.58	-27.09	-147.09	92.91
5	14 GJL BC	5	46610.98	46610.99	46610.98	2.77	-117.23	122.77
6	17 BEL BO	5	81114.11	81114.11	81114.11	3.39	-116.61	123.39
7	20 MCCL	URE BG	293848.04	293848.07	293848.04	-58.14	-178.14	61.86

	Number of Bus	Name of Bus	ID	Phase Cur A	Phase Cur B	Phase Cur C
1	4	Wells	1	205476.54922	18808.88130	190466.51934
2	5	Campus 13.2kV	1	31445.10622	31445.10622	31445.10622
3	6	Steam Plant	1	240469.37330	240469.37330	240469.37330
4	8	CNR	1	750352.76275	750352.76275	750352.76275
5	11	IRIC	1	187206.55320	187206.55320	187206.55320
6	13	GJL	1	26898.40825	26898.40825	26898.40825
7	16	BEL	1	46809.60342	46809.60342	46809.60342
8	19	MCCLURE	1	169574.81793	169574.81793	169574.81793

Steam Plant – Bus Fault – Single Line-to-Ground:

Bus Records:

	Number Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1 SOLAR BACKUI	1.00000	1.00000	1.00000	-30.57	-150.57	89.43
2	2 Array-Microgri	d. 0.99476	0.99476	0.99476	-1.02	-121.02	118.98
3	3 Wells transform	0.91118	0.91118	0.91118	1.76	-118.24	121.76
4	4 Wells	0.90563	0.90563	0.90563	1.27	-118.73	121.27
5	5 Campus 13.2kV	0.39888	0.99684	0.63571	39.93	-120.37	71.84
6	6 Steam Plant	0.21023	0.80360	0.93647	-74.29	-125.94	65.10
7	7 CNR XFMR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
8	8 CNR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
9	9 CNR BG	1.00000	1.00000	1.00000	-30.05	-150.05	89.95
10	10 IRIC XEMR	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
11	11 IRIC	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
12	12 GJL XFMR	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
13	13 GJL	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
14	14 GJL BG	1.00000	1.00000	1.00000	29.34	-90.66	149.34
15	15 BEL XFMR	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
16	16 BEL	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
17	17 BEL BG	1.00000	1.00000	1.00000	29.32	-90.68	149.32
18	18 MCCLURE XFM	R 0.99935	0.99935	0.99935	-0.67	-120.67	119.33
19	19 MCCLURE	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
20	20 MCCLURE BG	1.00000	1.00000	1.00000	-30.60	-150.60	89.40

Lines:

	From Number	From Name	To Numbe	To Name	Circuit	Xfrmr	Phase Cur A From	Phase Cur B From	Phase Cur C From	Phase Cur A To	Phase Cur B To	Phase Cur C To
1	1	SOLAR BAC	2	Array-Micro	1	YES	41546.23	41546.23	41546.23	1142519.50	1142519.38	1142519.38
2	0 02	Array-Micro	3	Wells trans	1	NO	1142520.63	1142520.63	1142520.63	41546.21	41546.21	41546.21
1		Array-Micro		Campus 13								
4	3	Wells trans	4	Wells	1	YES	41546.25	41546.24	41546.25	228504.34	228504.33	228504.34
5		Steam Plan	5	Campus 13	1	YES	660072.44	899154.56	1412861.50	12582,41	31445.11	20053.22
S		Campus 13		CNR MFMR	3	NO						
St 12		Comput 13		GJL XFMR		NO						
(1		Campul 13				NO						
1.00	1.1	Campus 13		MCCLURE >		NO						
10	6	CNR	7	CNR XFMR	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
8 11				IRUC OF MIL		NO						
12	5	CNR BG	8	CNR	1	YES	1300255.50	1300255.50	1300255.50	750354.44	750354.44	750354.44
13	11	IRIC	10	IRIC XFMR	1	YES	0.02	0.02	0.02	0.00	0.00	0.00
14	12	GILXFMR	13	GJL	1	TES	0.00	0.00	0.00	0.00	0.00	0.00
15	13	GJL	14	GJL BG	1	YES	26896.67	26896.67	26896.67	46610.46	46610.46	46610.46
16	15	EELXFMR	16	BEL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
17	16	5 BEL	17	BEL BG	1	YES	46809.79	46809.79	46809.78	81116.88	81116.88	81116.88
18	15	MCCLURE	18	MCCLURE >	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
19	20	MCCLURE E	19	MCCLURE	1	YES	293855.16	293855.16	293855.16	169577.42	169577.42	169577.41

Generators:

í	Number of Bus	Name of Bus	Phase Cur A	Phase Cur B	Phase Cur C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	41546.21	41546.21	41546.21	-64.27	175.73	55.73
2	6 9	Steam Plant	1908291.15	1004418.26	1611507.04	-82.23	156.56	65.52
3	9 (CNR BG	1300250.20	1300250.30	1300250.20	-56.20	-176.20	63.80
4	11 /	RIC	187206.57	187206.57	187206.58	-27.09	-147.09	92.91
5	14 (GJL BG	46610.98	46610.99	46610.98	2.77	-117.23	122.77
6	17 8	BEL BG	81114.11	81114.11	81114.11	3.39	-116.61	123.39
7	20 1	MCCLURE BG	293848.04	293848.07	293848.04	-58.14	-178.14	61.86

	Number of Bus	Name of Bus	ID	Phase Cur A	Phase Cur B	Phase Cur C
1	4 W	Vells	1	228504.14336	228504.14336	228504.14336
2	5 C	ampus 13.2kV	1	12582.43793	31445.10622	20053.22562
3	6 St	team Plant	1	50746.36205	192051.32472	226146.33873
4	8 C	INR	1	750352.76275	750352.76275	750352.76275
5	11 IF	RIC	1	187206.55320	187206.55320	187206.55320
6	13 G	5JL	1	26898.40825	26898.40825	26898.40825
7	16 B	EL	1	46809.60342	46809.60342	46809.60342
8	19 N	ACCLURE	1	169574.81793	169574.81793	169574.81793

Steam Plant – Bus Fault – Line-to-Line:

Bus Records:

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP /	1.00000	1.00000	1.00000	-30.57	-150.57	89.43
2	2	Array-Microgrid.	0.99476	0.99476	0.99476	-1.02	-121.02	118.98
3	3	Wells transform	0.91118	0.91118	0.91118	1.76	-118.24	121.76
4	4	Wells	0.90563	0.90563	0.90563	1.27	-118.73	121.27
5	5	Campus 13.2kV	0.89350	0.07768	0.83380	-28.78	-170.62	147.92
6	6	Steam Plant	1.00000	0.55357	0.45018	-30.00	154.47	144.50
7	7	CNR XFMR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
8	8	CNR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
9	9	CNR BG	1.00000	1.00000	1.00000	-30.05	-150.05	89.95
10	10	IRIC XFMR	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
11	11	IRIC	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
12	12	GJL XFMR	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
13	13	GJL	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
14	14	GJL BG	1.00000	1.00000	1.00000	29.34	-90.66	149.34
15	15	BEL XFMR	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
16	16	BEL	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
17	17	BEL BG	1.00000	1.00000	1.00000	29.32	-90.68	149.32
18	18	MCCLURE XFMR	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
19	19	MCCLURE	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
20	20	MCCLURE BG	1.00000	1.00000	1.00000	-30.60	-150.60	89.40

Lines:

	From Number	From Name	To Number	To Name	Circuit	Xfrmr	Phase Cur A From	Phase Cur B From	Phase Cur C From	Phase Cur A To	Phase Cur B To	Phase Cur C To
1	1	SOLAR BAC	2	Array-Micro	1	YES	41546.23	41546.23	41546.23	1142519.50	1142519.38	1142519.38
2	2	Array-Micro	3	Wells trans	1	NO	1142520.63	1142520.63	1142520.63	41546.21	41546.21	41546.21
1.3		(Array-Miere										
4	3	Wells trans	4	Wells	1	YES	41546.25	41546.24	41546.25	228504.34	228504.33	228504.34
5	6	Steam Plan	5	Campus 13	1	YES	864744.50	478700.16	389293.63	28185.28	2450.50	26301.96
1.5		Campus 13			3	NO						
- 71		Campus 13		G.IL XFMR	1	NO						
1.5		Camput 13		RELXEME -		NO						
- 9		Campul 13		MICCLURE >	1	NO						
10	8	CNR	7	CNR XFMR	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
193		CNR XEMR		IRIC XFMR		NO						
12	9	CNR BG	8	CNR	1	YES	1300255.50	1300255.50	1300255.50	750354.44	750354.44	750354.44
13	11	IRIC	10	IRIC XFMR	1	YES	0.02	0.02	0.02	0.00	0.00	0.00
14	12	GJL XFMR	13	GJL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
15	13	GJL	14	GJL BG	1	YES	26896.67	26896.67	26896.67	46610.46	46610.46	45610.46
16	15	BEL XFMR	16	BEL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
17	16	BEL	17	BEL BG	1	YES	46809.79	46809.79	46809.78	81116.88	81116.88	81116.88
18	19	MCCLURE	18	MCCLURE >	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
19	20	MCCLURE E	19	MCCLURE	1	YES	293855.16	293855.16	293855.16	169577.42	169577.42	169577.41

Generators:

	Number of Bus	Name of Bus	Phase Cur A	Phase Cur B	Phase Cur C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	41546.21	41546.21	41546.21	-64.27	175.73	55.73
2	6	Steam Plant	1105204.85	2024413.34	1481439.89	-56.12	169.58	21.86
3	9	CNR BG	1300250.20	1300250.30	1300250.20	-56.20	-176.20	63.80
4	11	IRIC	187206.57	187206.57	187206.58	-27.09	-147.09	92.91
5	14	GJL BG	46610.98	46610.99	46610.98	2.77	-117.23	122.77
6	17	BEL BG	81114.11	81114.11	81114.11	3.39	-116.61	123.39
7	20	MCCLURE BG	293848.04	293848.07	293848.04	-58.14	-178.14	61.86

	Number of Bus	Name of Bus	ID	Phase Cur A	Phase Cur B	Phase Cur C
1	4	Wells	1	228504.14336	228504.14336	228504.14336
2	5	Campus 13.2kV	1	28185.18772	2450.45978	26301.89217
3	6	Steam Plant	1	240469.38764	133117.49710	108255.44053
4	8	CNR	1	750352.76275	750352.76275	750352.76275
5	11	IRIC	1	187206.55320	187206.55320	187206.55320
6	13	GJL	1	26898.40825	26898.40825	26898.40825
7	16	BEL	1	46809.60342	46809.60342	46809.60342
8	19	MCCLURE	1	169574.81793	169574.81793	169574.81793

IRIC – Bus Fault – Single Line-to-Ground:

Bus Records:

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	1.00000	1.00000	1.00000	-30.57	-150.57	89.43
2	2	Array-Microgrid,	0.99476	0.99476	0.99476	-1.02	-121.02	118.98
3	3	Wells transform	0.91118	0.91118	0.91118	1.76	-118.24	121.76
4	4	Wells	0.90563	0.90563	0.90563	1.27	-118.73	121.27
5	5	Campus 13.2kV	0.99684	0.99684	0.99684	-0.37	-120.37	119.63
6	6	Steam Plant	1.00000	1.00000	1.00000	-30.00	-150.00	90.00
7	7	CNR XFMR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
8	8	CNR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
9	9	CNR BG	1.00000	1.00000	1.00000	-30.05	-150.05	89.95
10	10	IRIC XEMR	0.00000	1.73205	1.73205	-91.12	-151.19	148.81
11	11	IRIC	1.00000	1.00000	1.00000	-1.19	-121.19	118.81
12	12	GJL XFMR	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
13	13	GJL	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
14	14	GJL BG	1.00000	1.00000	1.00000	29.34	-90.66	149.34
15	15	BEL XFMR	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
16	16	BEL	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
17	17	BEL BG	1.00000	1.00000	1.00000	29.32	-90.68	149.32
18	18	MCCLURE XFMR	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
19	19	MCCLURE	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
20	20	MCCLURE BG	1.00000	1.00000	1.00000	-30.60	-150.60	89.40

Lines:

	From Number	From Name	To Number	To Name	Circuit	Xfrmr	Phase Cur A From	Phase Cur 8 From	Phase Cur C From	Phase Cur A To	Phase Cur B To	Phase Cur C To
1	1	SOLAR BAC	2	Array-Micro	1	YES	41546.23	41546.23	41546.23	1142519.50	1142519.38	1142519.38
2	2	Array-Micro	3	Wells trans	1	NO	1142520.63	1142520.63	1142520.63	41546.21	41546.21	41546.21
- 3		Array-Meerc	5	Camput 15	1							
4	3	Wells trans	4	Wells	1	YES	41546.25	41546.24	41546.25	228504.34	228504.33	228504.34
5	6	Steam Plan	5	Campus 13	1	YES	864741.56	864741.50	864741.50	31445,10	31445.10	31445.10
15		Campus 13			1	NO						
-7		Camput 13		GIL XFMR	3	NO						
-01		Campus 13		BEL XFMA	1	NO						
		Campus 13		MCCLURER		NO						
10	8	CNR	7	CNR XFMR	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
31		CNR XFMR		IRIC XPMR	1	NO						
12	9	CNR BG	8	CNR	1	YES	1300255.50	1300255.50	1300255.50	750354.44	750354.44	750354.44
13	11	IRIC	10	IRIC XFMR	1	YES	2.51	0.76	1.78	0.09	0.03	0.06
14	12	GJL XFMR	13	GJL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
15	13	GJL	14	GJL BG	1	YES	26896.67	26896.67	26896.67	46610.46	46610.46	46610.46
16	15	BEL XFMR	16	BEL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
17	16	BEL	17	BEL BG	1	YES	46809.79	46809.79	46809.78	81116.88	81116.88	81116.88
18	19	MCCLURE	18	MCCLURE)	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
19	20	MCCLURE E	19	MCCLURE	1	VES	293855.16	293855.16	293855.16	169577.42	169577.42	169577.41

Generators:

	Number of Bus Name of Bus	Phase Cur A	Phase Cur B	Phase Cur C	Phase Ang A	Phase Ang B	Phase Ang C
1	1 SOLAR BACKUP	41546.21	41546.21	41546.21	-64.27	175.73	55.73
2	6 Steam Plant	1105204.85	1105204.97	1105204.85	-56.12	-176.12	63.88
3	9 CNR BG	1300250.20	1300250.30	1300250.20	-56.20	-176.20	63.80
4	11 IRIC	187207.26	187205.82	187207.66	-27.09	-147.09	92.91
5	14 GJL BG	46610.98	46610.99	46610.98	2,77	-117.23	122.77
6	17 BEL BG	81114.11	81114.11	81114.11	3.39	-116.61	123.39
7	20 MCCLURE BG	293848.04	293848.07	293848.04	-58.14	-178.14	61.86

	Number of Bus	Name of Bus	ID	Phase Cur A	Phase Cur B	Phase Cur C
1	4	Wells	1	228504.14336	228504.14336	228504.14336
2	5	Campus 13.2kV	1	31445.10622	31445.10622	31445.10622
3	6	Steam Plant	1	240469.37330	240469.37330	240469.37330
4	8	CNR	1	750352.76275	750352.76275	750352.76275
5	11	IRIC	1	187206.22341	187206.49584	187206.45283
6	13	GJL	1	26898.40825	26898.40825	26898.40825
7	16	BEL	1	46809.60342	46809.60342	46809.60342
8	19	MCCLURE	1	169574.81793	169574.81793	169574.81793

IRIC – Bus Fault – Line-to-Line:

Bus Records:

	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP /	1.00000	1.00000	1.00000	-30.57	-150.57	89.43
2	2	Array-Microgrid,	0.99476	0.99476	0.99476	-1.02	-121.02	118.98
3	3	Wells transform	0.91118	0.91118	0.91118	1.76	-118.24	121.76
4	4	Wells	0.90563	0.90563	0.90563	1.27	-118.73	121.27
5	5	Campus 13.2kV	0.99684	0.99684	0.99684	-0.37	-120.37	119.63
6	6	Steam Plant	1.00000	1.00000	1.00000	-30.00	-150.00	90.00
7	7	CNR XFMR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
8	8	CNR	0.99727	0.99727	0.99727	-0.37	-120.37	119.63
9	9	CNR BG	1.00000	1.00000	1.00000	-30.05	-150.05	89.95
10	10	IRIC XFMR	1.00000	0.54173	0.45883	-1.19	-179.43	176.74
11	11	IRIC	1.00000	0.62642	0.37887	-1.19	-176.62	171.25
12	12	GJL XFMR	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
13	13	GJL	0.99990	0.99990	0.99990	-0.67	-120.67	119.33
14	14	GJL BG	1.00000	1.00000	1.00000	29.34	-90.66	149.34
15	15	BEL XFMR	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
16	16	BEL	0.99983	0.99983	0.99983	-0.70	-120.70	119.30
17	17	BEL BG	1.00000	1.00000	1.00000	29.32	-90.68	149.32
18	18	MCCLURE XFMR	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
19	19	MCCLURE	0.99935	0.99935	0.99935	-0.67	-120.67	119.33
20	20	MCCLURE BG	1.00000	1.00000	1.00000	-30.60	-150.60	89.40

Lines:

	From From Na Number	ne To Numb	er To Name	Circuit	Xfrme	Phase Cur A From	Phase Cur B From	Phase Cur C From	Phase Cur A To	Phase Cur B To	Phase Cur C To
1	1 SOLAR B	AC	2 Array-Micro	1	YES	41546.23	41546.23	41546.23	1142519.50	1142519.38	1142519.38
2	2 Array-Mi	rc	3 Wells trans	1	NO	1142520.63	1142520.63	1142520.63	41546.21	41546.21	41546.21
0	2 Artay-M				NO						
- 4	3 Wells tra	ns	4 Wells	1	YES	41546.25	41546.24	41546.25	228504.34	228504.33	228504.34
5	6 Steam Pl	in:	5 Campus 13	1	YES	864741.56	864741.50	864741.50	31445.10	31445.10	31445.10
6	5 Campus		7 CNR XFMR		NO						
3 11	5 Campus		2 GR XPMR	1	NO						
1	5 Campus		5 DEL YFMI	1	NO						
19	5 Campus		B. MCCLURE 3	(1	NO						
10	8 CNR		7 CNR XFMR	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
3.1	7 CNR XPA		D IRIC REMAR		NO						
12	9 CNR BG		8 CNR	1	YES	1300255.50	1300255.50	1300255.50	750354.44	750354.44	750354.44
13	11 IRIC		10 IRIC XFMR	1	YES	0.00	1069604.38	1069604.38	0.00	38894.70	38894.70
14	12 GJL XFM	5	13 GJL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
15	13 G/L		4 GJL BG	1	YES	26896.67	26896.67	26896.67	46610.46	46610.46	46610.46
16	15 BEL XFM	8	16 BEL	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
17	16 EEL		7 BEL BG	1	YES	46809.79	46809.79	46809.78	81116.88	81116.88	81116.88
18	19 MCCLUR	E	18 MCCLURE 1	1	YES	0.00	0.00	0.00	0.00	0.00	0.00
19	20 MCCLUR	EE	9 MCCLURE	1	YES	293855.16	293855.16	293855.16	169577.42	169577.42	169577.41

Generators:

	Number of Bus	Name of Bus	Phase Cur A	Phase Cur B	Phase Cur C	Phase Ang A	Phase Ang B	Phase Ang C
1	1	SOLAR BACKUP	41546.21	41546.21	41546.21	-64.27	175.73	55.73
2	6	Steam Plant	1105204.85	1105204.97	1105204.85	-56.12	-176.12	63.88
3	9	CNR BG	1300250.20	1300250.30	1300250.20	-56.20	-176.20	63.80
4	11	IRIC	187206.60	1164858.11	1025067.86	-27.09	-168.56	17.97
5	14	GJL BG	46610.98	46610.99	46610.98	2.77	-117.23	122.77
6	17	BEL BG	81114.11	81114.11	81114.11	3.39	-116.61	123.39
7	20 1	MCCLURE BG	293848.04	293848.07	293848.04	-58.14	-178.14	61.86

Loads:

	Number of Bus	Name of Bus	ID	Phase Cur A	Phase Cur B	Phase Cur C
1	4	Wells	1	228504.14336	228504.14336	228504.14336
2	5	Campus 13.2kV	1	31445.10622	31445.10622	31445.10622
3	6	Steam Plant	1	240469.37330	240469.37330	240469.37330
4	8	CNR	1	750352.76275	750352.76275	750352.76275
5	11	IRIC	1	187206.55320	117268.99513	70927.49842
6	13	GJL	1	26898.40825	26898.40825	26898.40825
7	16	BEL	1	46809.60342	46809.60342	46809.60342
8	19	MCCLURE	1	169574.81793	169574.81793	169574.81793

The fault analysis provides a selection of switches, as well as the setting of relays and stability of the system operation. This analysis evaluated the faults at each of the individual bus fault generation source (IRIC, Steam Plant, and Solar Backup PV Array). Each analysis from the generation source consisted of a line to line and a line to ground fault. Depending on the generation source there is a small difference of about 0.8 phase voltage difference. Each analysis shows not only the fault voltages and phase angles but also the fault currents and phase angles.

N-1 Contingency Analysis



Figure 1. Power Flow Worst Case Scenario

To do the N-1 contingency analysis, make sure you lost just one element in the system.

As is shown in the figure 1, I disconnect the transmission line between Campus 13.2kV bus and connection with every building including Array-Microgrid/Array-Wells bus, then I run the

mode, it shows that each generator operates with their own load. Then we click the 'contingency analysis' at the menu bar to analyze the result.

	Label	Skip	Category	Processed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violation	Violation	s
1	T_000001SOLARBACKUPARRAY-000002Array-Microgrid/Array-WellsC1	NO	1	YES	YES	YES	NO	none	700.00		0	0	0	0		0
2	T_000002Array-Microgrid/Array-Wells-000003WellstransformerC1	NO		YES	YES		NO	none	700.00		0	0	0	0	1	0
3	T_000002Array-Microgrid/Array-Wells-000005Campus13.2kVbusC1	NO		YES	YES	YES	NO	none			0	0	0	0	1	0
4	T_000003Wellstransformer-000004WellsC1	NO		YES	YES		NO	none	700.00		0	0	0	0	1	0
5	T_000006SteamPlant-000005Campus13.2kVbusC1	NO		YES	YES	YES		none	645.00		0	0	0	0	1	0
6	L_000005Campus13.2kVbus-000007CNRXFMRC1	NO		YES	YES		NO	none			0	0	0	0		0
7	L_000005Campus13.2kVbus-000012GJLXFMRC1	NO		YES	YES		NO	none			0	0	0	0		0
8	L_000005Campus13.2kVbus-000015BELXFMRC1	NO		YES	YES	YES	NO	none			0	0	0	0	1	0
9	L_000005Campus13.2kVbus-000018MCCLUREXFMRC1	NO		YES	YES	YES		none			0	0	0	0		0
10	T_000008CNR-000007CNRXFMRC1	NO		YES	YES		NO	none			0	0	0	0		0
11	L_000007CNRXFMR-000010IRICXFMRC1	NO		YES	YES	YES	NO	none			0	0	0	0	1	0
12	T_000009CNRBG-000008CNRC1	NO		YES	YES	YES	NO	none	560.00		0	0	0	0	1	0
13	T_000011IRIC-000010IRICXFMRC1	NO		YES	YES	YES		none			0	0	0	0	1	0
14	T_000012GJLXFMR-000013GJLC1	NO		YES	YES	YES		none			0	0	0	0	1	0
15	T_000013GJL-000014GJLBGC1	NO		YES	YES	YES	NO	none	20.00		0	0	0	0	(0
16	T_000015BELXFMR-000016BELC1	NO		YES	YES	YES	NO	none			0	0	0	0		0
17	T_000016BEL-000017BELBGC1	NO		YES	YES		NO	none	35.00		0	0	0	0		0
18	T_000019MCCLURE-000018MCCLUREXFMRC1	NO		YES	YES		NO	none			0	0	0	0		0
19	T_000020MCCLUREBG-000019MCCLUREC1	NO		YES	YES	YES	NO	none	125.00		0	0	0	0		0
20	G_000001SOLARBACKUPARRAYU1	NO		YES	YES	YES	NO	none	700.00		0	0	0	0		0
21	G_000006SteamPlantU1	NO		YES	YES			none	825.00		0	0	0	0	1	0
22	G_000009CNRBGU1	NO		YES	YES		NO	none	560.00		0	0	0	0	1	0
23	G_000011IRICU1	NO		YES	YES		NO	none	140.00		0	0	0	0	1	0
24	G_000014GJLBGU1	NO		YES	YES	YES	NO	none	20.00		0	0	0	0		0
25	G_000017BELBGU1	NO		YES	YES		NO	none	35.00		0	0	0	0	1	0
26	G_000020MCCLUREBGU1	NO		YES	YES		NO	none	125.00		0	0	0	0		0

Figure 2. Contingency analysis for case 1

Then I click the 'Auto Insert' at the bottom left, for me, I choose to insert single transmission line or transformer and single generating unit into the table in order to show us the result when opening each of them the circumstance for the mode, then I click start run at the bottom right, it shows the result for the analysis in the figure 2.

For the Label column, it shows the actions we did, and also, we can clearly see the action at the bottom right table when we select any label in the table.

For the violation column, it completely shows '0', it means the system has no overloaded line, what if it shows '1', then it means there should have overloaded lines.

For the islanded load column, it means when you disconnect one element, you will loss the corresponding power, like the first row, if we disconnect the transformer between solar backup array and Array-Microgrid/Array-Wells, then we will loss 700 MW power.

Why the system has no violation? Because each bus has its own generation source, and no connection with other sources, each source feeds its own load, no connection between source and source.



Figure 3. Disconnection of Solar backup array generator

As is shown in the figure 3, if I disconnect the solar backup array generator and click run mode, there are no overloaded lines come out in the mode and that confirm the result.

Case 2:



Figure 4. Power Flow Best Case Scenario

As is shown in the figure 4, I connect the buses between Campus 13.2kV bus and Array-Microgrid/Array-Wells bus, click run mode, then we begin our analysis for the mode.

	Label	Skip	Category Proc	essed	Solved	Include Remedial Actions	Screen Allow	Post-CTG AUX	Islanded Load	Islanded Gen	Global Actions	Transient Actions	Remedial Actions	Custom Monitor Violations	Violations	Max Branch %	Min Volt	Max Volt	Max Interface %	Max Bus Pair Angle	1
1	_000001SOLARBACKUPARRAY-000002Array-Microgrid/Array-WellsC1	NO	YES	YE	ES	YES	NO .	none			0) (0 0	4	120.7	0.790)			1
2	_000002Array-Microgrid/Array-Wells-000003WellstransformerC1	NO	YES	YE	ES			none	700.00		0	() (0 0	0)					
3	_000002Array-Microgrid/Array-Wells-000005Campus13.2kVbusC1	NO	YES	Y	ES			none			0	() (0 0	0)					
4	_000003Wellstransformer-000004WellsC1	NO	YES	Y	ES			none	700.00		0) (0 0	0)					
5	_000006SteamPlant-000005Campus13.2kVbusC1	NO	YES	Y	ES			none			0	() (0 0	0)					
6	_000005Campus13.2kVbus-000007CNRXFMRC1	NO	YES	Y	ES			none			0		0 0	0 0	0	0					
7	_000005Campus13.2kVbus-000012GJLXFMRC1	NO	YES	Y	ES			none			0	() (0 0	0)					
8	_000005Campus13.2kVbus-000015BELXFMRC1	NO	YES	Y	ES			none			0	() (0 0	0)					
9	_000005Campus13.2kVbus-000018MCCLUREXFMRC1	NO	YES	Y	ES			none			0		0	0 0	0)					
10	_000008CNR-000007CNRXFMRC1	NO	YES	Y	ES			none			0) (0 0	0)					
11	_000007CNRXFMR-000010IRICXFMRC1	NO	YES	Y	ES			none			0	() (0 0	0)					
12	_000009CNRBG-000008CNRC1	NO	YES	Y	ES	YES 7		none	560.00		0	() (0 0	0)					
13	_0000111RIC-000010IRICXFMRC1	NO	YES	Y	ES	YES 7		none			0) (0 0	0)					
14	000012GJLXFMR-000013GJLC1	NO	YES	YE	ES			none			0) (0 0	0)					
15	_000013GJL-000014GJLBGC1	NO	YES	Y	ES			none	20.00		0) (0 0	0)					
16	_000015BELXFMR-000016BELC1	NO	YES	Y	ES	VES 1		none			0) (0 0	0)					
17	_000016BEL-000017BELBGC1	NO	YES	Y	ES	VES I		none	35.00		0) (0 0	0)					
18	_000019MCCLURE-000018MCCLUREXFMRC1	NO	YES	Y	ES			none			0	() (0 0	0)					
19	_000020MCCLUREBG-000019MCCLUREC1	NO	YES	Y	ES	YES 1		none	125.00		0) (0 0	0)					
20	000001SOLARBACKUPARRAYU1	NO	YES	YE	ES			none			0) (0 0	5	120.7	0.790)			
21	_000006SteamPlantU1	NO	YES	YE	ES			none			0	() (0 0	2		0.892	2			
22	_000009CNRBGU1	NO	YES	Y	ES	YES 1		none	560.00		0) (0 0	0)					
23	_000011IRICU1	NO	YES	YE	ES			none	140.00		0) (0 0	0)					
24	_000014GJLBGU1	NO	YES	Y	ES	VES 1		none	20.00		0) (0 0	0	0					
25	_000017BELBGU1	NO	YES	Y	ES			none	35.00		0) (0 0) ()					
26	_000020MCCLUREBGU1	NO	YES	Y	ES			none	125.00		0) (0 0	0)					
¢																					
Violation	8 What Actually Occurred												Definition								×
Show	related contingencies Combined Tables >															Action				Mo	
	Category Element	Value	Limit	Pero	cent	Area Name Assoc.	Nom	kV Assoc.					10	PEN Transfe	ormer SOLA	R BACKUP A	RAY 13.2	(1) TO An	ray-Microg		
1	Branch MVA Steam Plant (6) -> Campus 13.2kV bus (5) CK	1810.4	5 1500.00)	120.70	1		13.20	3												
2		0.892	5 0.9000)	99.17	1		0.48													
	Bus Low Volts Array-Microgrid/Array-Wells (2)	0.000																			
3	Bus Low Volts Array-Microgrid/Array-Wells (2) Bus Low Volts Wells transformer (3)	0.796	5 0.9000)	88.50	1		13.20													
3	Bus Low Volts Array-Microgrid/Array-Wells (2) Bus Low Volts Wells transformer (3) Bus Low Volts Wells (4)	0.796	5 0.9000 1 0.9000	0	88.50 87.79	1		13.20 2.40													

Figure 5. Contingency analysis for Best Case Scenario

When we click 'start run' at the bottom right, the result is shown in the table, the first row shows that the violation is 4, it means the transformer between solar backup array and Array-Microgrid/Array-Wells is 5 overloaded, the Max Branch Percent means the maximum power overloaded percentage we will see in the system. The min volt means that one of the buses that the voltage is going down by 0.790.

Also, if we select one label, the violations will be clearly shown at the bottom left table in detail corresponding to the label. At this table, the value means that the voltage will go down to the value at this bus, and the limit means the regular voltage corresponding to the element.

Label	Element	Category	Value	Limit	Percent CTG Specified	Limit Scale
					Limit	
1 T 000001SOLARBACKUPARRAY-000002Array-Microgrid/Array-WellsC1	Steam Plant (6) -> Campus 13.2kV bus (5) CKT 1 at Steam Plant	Branch MVA	1810.45	1500.00	120.70 NO	1500.00
2 G_000001SOLARBACKUPARRAYU1	Steam Plant (6) -> Campus 13.2kV bus (5) CKT 1 at Steam Plant	Branch MVA	1810.51	1500.00	120.70 NO	1500.00
3 G_000001SOLARBACKUPARRAYU1	SOLAR BACKUP ARRAY (1)	Bus Low Volts	0.8925	0.9000	99.17 NO	0.9000
4 T_000001SOLARBACKUPARRAY-000002Array-Microgrid/Array-WellsC1	Array-Microgrid/Array-Wells (2)	Bus Low Volts	0.8925	0.9000	99.17 NO	0.9000
5 G_000001SOLARBACKUPARRAYU1	Array-Microgrid/Array-Wells (2)	Bus Low Volts	0.8925	0.9000	99.17 NO	0.9000
6 T_000001SOLARBACKUPARRAY-000002Array-Microgrid/Array-WellsC1	Wells transformer (3)	Bus Low Volts	0.7965	0.9000	88.50 NO	0.9000
7 G_000001SOLARBACKUPARRAYU1	Wells transformer (3)	Bus Low Volts	0.7965	0.9000	88.50 NO	0.9000
8 T_000001SOLARBACKUPARRAY-000002Array-Microgrid/Array-WellsC1	Wells (4)	Bus Low Volts	0.7901	0.9000	87.79 NO	0.9000
9 G_000001SOLARBACKUPARRAYU1	Wells (4)	Bus Low Volts	0.7901	0.9000	87.79 NO	0.9000
10 G_000006SteamPlantU1	Campus 13.2kV bus (5)	Bus Low Volts	0.893	0.9000	99.22 NO	0.9000
11 G_000006SteamPlantU1	Steam Plant (6)	Bus Low Volts	0.892	0.9000	99.11 NO	0.9000

Figure 6. Contingency violation list table

Click the combined table above the violations table and choose to show the contingency violation list so that we can see all the violations in the figure 6.



Figure 7. Disconnection of solar backup array generator

Now, if I disconnect the solar backup array generator shown in the figure 7, then I click run mode, it clearly shows that between the steam plant bus and Campus 13.2 KV bus, there is a maximum power overloaded percent in the system and that confirm the data in the result table.



Figure 8. Disconnection of steam plant generator

² Also, if I disconnect the steam plant generator shown in the figure 8, then I click run mode, there will be no place that overloaded and that also confirm the data in the result table.

What's more, I can disconnect other single elements, disconnect one element each time, including generator or transformer and generating unit for confirming the result.

Load Shedding Analysis

For all electrical equipment, there is a rated voltage, but in practice, it is not completely guaranteed to work at the rated voltage, which is a range around the rated voltage, generally required to be $\pm 10\%$. In order to protect the electrical equipment and process quality, if the voltage is lower than -10%, it is "undervoltage". When the operating voltage drops below this voltage, the protection action will cut off the power supply.

1. The initial power of the steam turbine generator is 1000MVA, I changed it to 900MVA to simulate the load in the undervoltage state.

US Number Bus Name Steam ID 1 Inrea Name 1 (1) Labels no lab Genera rower and Voltage C Power Control MW Output 8 Min. MW Output 1 Voltage Control Mvar Output 254. Min Mvar 9900 Wind Control Mod Mode None MW Min Mvar Max Mvar Max Mvar Mode None	n Plant pels ator MVA Bas control Cos 825.000 0.000 1000.000 .752	✓ ✓	Faults Faults Faults Faults r AVR ity Curv Por	By Number d By Name Find Owners, GC Pa nits during rol Reg Desire /e Actua wer Factor 1.0000	Status Op Clo Clo Energi NO Evel Typ Unit Typ Area, etc. Inticipation F Loss Sens Ulated Bus M d Reg. Bus M Remote	en sed zed (Offine) S (Online) De Woo Pe ST (Custom Custom Custom actor 10 itivity 0.0	ad or Wood W Steam Turbine Stability .00 .000 .00000 .000000 50.0	'aste e)
Bus Name Steam ID 1 rea Name 1 (1) Labels no lab Genera ower and Voltage C Power Control MW Output [MW Output 1 NW Output 254. Min Mvar 9900 Wind Control Mo Mode None MW Min Mvar 4 Mode None	n Plant	× se 900.00 sts OPF Available Available Available for Use Capabili	Faults Faults Faults r AVR ity Curv Pon	Owners, Owners, GC Pa nits during rol Reg Desire /e Actua wer Factor 1.0000	Control Contr	sed zed (Offline) S (Online) S (Online	ad or Wood W Steam Turbine Stability .00 .00 .000 .000 .00000 .000000 50.0	'aste 2)
ID 1 rea Name 1(1) Labels no lab Genera ower and Voltage C ower Control MW Output 1 din. MW Output 1 foltage Control Avar Output 254. Min Mvar 9900 Wind Control Mo Mode None MW Min Mvar 4 Mode None	pels ator MVA Bas Control Cos 825.000 0.000 1000.000 0.000 752 2 00.000 0 0.000 0	Ise 900.00 sts OPF Available Carteria automat	Faults Fa	Find Owners, GC Pz nits during rol Reg Desire ye Actua wer Factor 1.0000	Energi NO NO Fuel Typ Unit Typ Area, etc. Inticipation F Loss Sens Ulated Bus N d Reg. Bus N I Reg. Bus N Remote	zed (Offine) S (Online) De Woo De ST (Custom Custo	od or Wood W Steam Turbine Stability .00 .000 .000 .000000 50.0	iaste e)
rea Name 1 (1) Labels no lab Genera ower and Voltage C ower Control MW Output in. MW Output iax. MW Output	eels ator MVA Bas Control Cos 825.000 0.000 1000.000 	se 900.00 sts OPF] □ Available] □ Available] □ Enforce automat	Faults Faults MW Lim tic contr r AVR lity Curv Por	Owners, GC Pa nits during rol Reg Desire ve Actua wer Factor 1.0000 ÷	Fuel Typ Unit Typ Area, etc. Inticipation F Loss Sens Ulated Bus M d Reg. Bus M Reg. Bus M Remote	S (Online) Mode Wood S (Custom Cust	d or Wood W Steam Turbine Stability .00 000	'aste ε)
Labels no lab Genera ower and Voltage C Power Control MW Output [Ain. MW Output 1 foltage Control Avar Output 254. Min Mvar 9900 Wind Control Mo Mode None MW Min Mvar 4	eels ator MVA Bas Control Cos 825.000 0.000 1000.000 .752 0.000 0.	se 900.00 sts OPF Available PEnforce automat Available for Use Capabili	Faults He for AC MW Lim tic contr r AVR lity Curv	Owners, GC Pa nits during rol Reg Desire ve Actua wer Factor 1.0000	Fuel Typ Unit Typ Area, etc. Inticipation F Loss Sens Ulated Bus M d Reg. Bus M Reg. Bus M Remote	e Woo e ST (Custom actor 10 itivity 0.0 umber 6 /oltage 1 /oltage 1 Reg %	od or Wood W Steam Turbine Stability .00 .000 .000 .000000 .000000 50.0	e)
General ower and Voltage C hower Control MW Output [in. MW Output 1 foltage Control Avar Output 254. Min Mvar 9900 Wind Control Mc Mode None WW Vin Mvar 4 Max Mvar 2 MW	ator MVA Bas Control Cos 825.000 0.000 1000.000 752 2 0.000 0.000 0.000	se 900.00 sts OPF Available Enforce automat Available for Use Capabili	Faults Faults MW Lim tic contr r AVR lity Curv Por	Owners, GC Pa nits during rol Reg Desire Actua wer Factor 1.0000	Unit Typ Area, etc. Inticipation F Loss Sens Ulated Bus N d Reg. Bus N I Reg. Bus N Remote	e ST (; Custom actor 10 itivity 0.0 umber 6 /oltage 1 /oltage 1 Reg %	Steam Turbine Stability .00 .000 .00000 50.0	=)
ower and Voltage C ower Control MW Output [in. MW Output [ax. MW Output [ioltage Control fvar Output 254, Min Mvar 9900 Max Mvar 9900 Wind Control Mc Mode None MW Min Mvar Max Mvar 2 MW	Control Cos 825.000 0.000 1000.000 752 2 0.000 0.000 0.000	sts OPF Available Characteristic Available for Use Capabili	Faults Ie for AC MW Lim tic contr r AVR lity Curv Por	Owners, GC Pa nits during rol Reg Desire Actua wer Factor 1.0000	Area, etc. Inticipation F Loss Sens Ulated Bus M d Reg. Bus M l Reg. Bus M Remote	Custom actor 10 itivity 0.0 Aumber 6 /oltage 1 /oltage 1 Reg %	Stability .00 000 5 1.000000 50.0	
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MW Output	825.000 0.000 1000.000 .752 0.000 0.] □ Available □ □ Enforce □ automat □ Available for □ Use Capabili	e for AC MW Lin tic contr r AVR lity Curv Por	GC Pa nits during rol Reg Desire Actua wer Factor 1.0000	ulated Bus N d Reg. Bus N Reg. Bus N Remote	actor 10 itivity 0.0 itivity 0.0 itivity 0.0 itivity 0.0 itivity 0.0 itivity 0.0	.00 0000 5 1.000000 50.0	
in. MW Output	0.000 1000.000 .752 2 00.000 0.000 0 ode	Available for	r AVR lity Curv Por	nits during rol Desire Actua wer Factor 1.0000	Loss Sens ulated Bus N d Reg. Bus N l Reg. Bus N Remote	itivity 0.0 iumber 6 /oltage 1 /oltage 1 Reg %	5 1.000000 1.000000 50.0	
MW Output ax. MW Output 1 ax. MW Output 1 ax. MW Output 1 oltage Control 1 Ivar Output 254. Min Mvar -990 Max Mvar 9900 Wind Control Mc Mode None 1 1 Mw 1 Iax Mvar 1 OK 0	0.000 1000.000 .752 0.000 0.000 ode	Available for	r AVR ity Curv Po	rol Reg Desire Actua wer Factor 1.0000	Loss Sens ulated Bus N d Reg. Bus N l Reg. Bus N Remote	lumber 6 /oltage 1 /oltage 1 Reg %	5 1.000000 1.000000 50.0	
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CK	.752 2 10.000 0 0.000 0 ode] Available for Use Capabili	er AVR lity Curv Por	Reg Desire Actua wer Factor 1.0000	lated Bus M Reg. Bus Reg. Bus Remote	lumber 6 /oltage 1 /oltage 1 Reg % [5 1.000000 1.000000 50.0	
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Min Mvar -990 Max Mvar 9900 Wind Control Mc Mode None MV Min Mvar Max Mvar	0.000 0.000 ode]Use Capabili	Por	Desire Actuation wer Factor	d Reg. Bus l Reg. Bus Remote	/oltage [1 /oltage [1 Reg % [1.000000 1.000000 50.0	
Min Mvar 4990 Max Mvar 9900 Wind Control Mc Mode None MW Min Mvar Max Mvar	0.000 0.000]Use Capabili	Por	Actuation Merina Actuation Merina Actuation Merina Actuation Merina Actuation Merina Actuation A	Reg. Bus N	/oltage 1 /oltage 1 Reg %	1.000000 1.000000 50.0	
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Wind Control Mc Mode None Win Mvar Max Mvar	ode		Por	wer Factor	Remote	Reg %	50.0	
Wind Control Mc Mode None 1W Vin Mvar Max Mvar	ode		Y Por	1.0000	Remote	Reg %	50.0	
Mode None			~	1.0000 ‡		_		
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MW Min Mvar Max Mvar								
Ain Mvar Aax Mvar					1			
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		101-00						
Number Juana Area Nar	une Non KY P	PU Volt Volt BOS	Angle Degi	Load MW Load M	ar Ges MW 0	ien Maar Switch	Ned Ad GShund Ad B	Shunt Aces Num Zone
1 SOLAR BACKU I 2 Antal African I	13-20	1.00000 13.300	30.57		794.17	\$22.56	0.00	0.00
3 Wells transfer 1 4 Wells	12,20	0.91123 12.025 0.90568 2.154	1.76	700.00 5	0.00		0.00	0.00
5 Category 12.26 X 6 Strans Rant, 1	6.48 0.48	8.69554 ¥3.118 1.00000 E.400	-1-34 -30-97	645.00 2 180.00	2.58 7.00 825.00	254.75	0.00	0.00 3 0.00 1
7 CNR XYSBE 1 8 CNR 1	13.20 0.48	0.99052 13.130 0.99799 0.479	-1.34	560.00 Z	1.00		0.00	0.00
9 CNR RG 1 10 RISC XFMR	0.28	0.00000 0.517	-11-02		560.96	212.12	0.00	0.00
12 GA WAR	0.48	1.00000 0.480	1.64	140.00	0.00 140.00	545.37	0.00	6.00
14 GA 80	13.20	0.00000		and a second sec			0.00	0.00
16 001 1	13.20 0.48 0.28	0.99938 0.430	25.37	and a	20.00	42.57	0.00	0.00
18 MCCLURE KPN 1	13.20 0.48 0.28 13.20 0.48	0.99935 0.400 1.00000 0.277 0.99855 13.185 0.99813 0.400	26.37	15.00	20.00	62.57	0.00	0.00

2. In the case of undervoltage, I simulated the load after shedding CNR, GJL, BEL, and MCCLURE

a. Shed the BEL load



1,11041	Advanced, 9	2 Bys					ma., Remove	QUICEPIER *								
	Rumber	Name	Area Name	Nom kV	PU Volt	Volt (R1)	Angle (Deg)	Load MW	Load Mear	Gen MW	Gen Miar	Switched Shunts Miler	Act G Shunt MW	Act 8 Shunt Mear	Area Num	Zone Num
1		SOLAR BACKU	3	13.20	1.00000	13,200	430,57			792.30	521.66		0.00	0.00		<u> </u>
- 2	2	Array Microgri	1	0.46	0.99481	0.478	1.02						0.00	0.00		
2	1	Wells transfor	1	15.20	0.91124	12.028	1.75						0.00	0.00		
- 4		Wells	1	2.40	0.90569	2,174	1.27	700.00	500.00				0.00	0.00		
		Campul 13.2x	1	13.20	0.99811	13.175	-1.45	645.00	312.38				0.00	0.00	1.1	
6	- 6	Steam Plant	1	0.48	1.00000	0.450	-31,09	180.00	87.00	825.00	277.90		0.00	0.00		
7	1	CHR HPARE	1	\$3.20	0.99841	13.179	-1.46						0.00	0.00	11	
. 8		CNR	1	0.48	0.99784	6.479	-1.46	560.00	271.00				0.00	0.00		
		CNR BG	1	0.30	1,00000	0.277	-31.54			560.00	217.60		0.00	0.00		
10	10	SPEC SPARE	3	15.20	0.99917	13,789	-1.96						0.00	0.00		
- 11	11	第に	3	0.48	1.00000	0.400	-2.46	140.00	68.00	340.00	155.07		0.00	0.00		
12	12	G.R. XPMR	1	91.20	0.99670	13,103	-1.81						0.00	0.00		
13	13	GR	1	0.45	0.99930	0.450	1.111	20.00	10.00				0.00	0.00		
14	54	GR BG	1	0.28	1.00000	0.277	26.21			20.00	70.24		0.00	0.00		
	15	RELXENR	1	13.30	0.99963	13,198	-0.70						0.00	0.00	6.1	
16	16	581	3	0.48	0.099963	0.450	-0.70	35.00	17.00				0.00	0.00	1.1	
+7	. 57	REL OG	1	6.28	1,00000	0.277	29.32			35.00	17.02		0.00	0.00		
1.8	10	ACCOUNT OF	1	\$3.30	0.9985.2	13,180	-1.70						0.00	0.00		
10	19	MCCLURE	1	0.40	0.99893	0.479	1.70	125.00	65.00				0.00	0.00		
20	20	MCCULIEE BG	1	0.28	1.00000	0.277	-31.43			125.00	106.75		0.00	0.00		

b. Shed the CNR load



Number	Name	Area Name	Nom kV	PU Volt	Volt (k1)	Angle (Degi	Load MW	Load Mvar	Gen MW	Gen Mvar	Switched Shunts Mvar	Act G Shunt MW	Act 8 Shunt Mear	Area filum	Zone Num
	SOLAR BACKU	1	13.20	1.00000	13,200	-30.57			790.96	522.86		0.00	0.00		
	Array Microgri	1	0.48	0.99480	0.478	-1.02						0.00	0.00	1	
1	Wells transfor	1	13.20	0.91123	12.028	1.76						0.00	0.00	. 1	
1 .	Wells	1	2.40	0.90567	2,174	1.27	700.00	500.00				0.00	0.00	1	
	Campus 13.2k	1	13.70	0.99826	13.177	1.11	645.00	512.38				0.00	0.00		
	5 Steam Plant	1	0.45	1,00000	0.480	-35.94	180.00	87.00	825.00	263.43		0.00	0.00		
	CNR SFMR	1	13.20	0.99068	12.102	-1.34						0.00	0.00		
	S CNR	1	0.48	0.99798	0.479	1.34	\$60.00	271.00				0.00	0.00	1	
	CNR 85	1	0.28	1.00000	0.277	-31.02			560.98	203.95		0.00	0.00	1	
3	RIC XTMR	1	53.20	0.99932	13.191	.1.75						0.00	0.00	. 1	
1 1	SIREC .	1	0.48	1.00000	0.480	-2.15	140.00	68.00	140.00	138.76		0.00	0.00		
1.	GR XFMR	1	13.20	0.99879	13.184	-1.62						0.00	0.00	- 1	
1	GR.	1	0.45	0.99935	0.480	-1.53	20.00	10.00				0.00	0.00	1	
1 1	6.R.85	1.	0.28	1.00000	0.277	28.55			20.00	65.32		0.00	0.00	1	
1	S BEL XPAIR	1	13.20	0.99877	12,164	-1.61						0.00	0.00	1	
3	5.8EL	1	0.48	0.99930	0.450	-1.61	35.00	17.00				0.00	0.00	1	
1	T BEL BG	1	0.20	1.00000	0.277	28.41			35.00	69.95		0.00	0.00	1	
3	MCCLURE RPM	1	13.20	0.99562	13,182	-1.52						0.00	0.00		
9	MCCLURE	1	0.45	0.99695	0.480	-1.52	125.00	65.00				0.00	0.00		
2	MCCLURE 8G	1.	0.25	1.00000	0.277	.31.45			125.00	101.86		0.00	0.00		

c. Shed the GJL load



	Number	Name	Area Name	Non XV	PUVUE	VUEAVI	Angle (Deg)	Load MW	Load bloar	Gen.MW	Gen Muar	Switched Shunts Mear	Act & Shunt	Act & Shurt	Area tours	Zone Num
1	· 1	SOLAR BACKU	1	13.20	1.00000	13.300	-30.37			791.27	522.70		0.00	2.00	2.1	
2		Artisy Marridal	1	0.45	0.99480	0.478	-5.62						0.00	0.00	1	
3	3	Wells transfer	1	13.20	0.81123	12.028	1.76						0.00	6.00		
4		Wells .		2.45	0.00548	-2.174	8.22	700.00	\$00.00				-0.00	0.00		
· ·	2 1	Campus 12.24	1	13.20	0.00010	11.171		645.00	312.38				6.00	.0.00		1
4	. 4	Dean Plant	1	0.44	1,00000	6.480	-30.87	180.00	\$7.00	825.00	278.52		6.00	0.00		
7	3	CNR MINE	1	15.20	0.99541	13,179	15.34						0.00	0.00	1	
6.	6	CNR .	1	0.48	0.99784	0.479	-1.34	560.00	271.00				6.00	0.00		
	5	CNR 105	8	0.25	1.00000	0.277	125.05			560.98	217.77		0.00	0.00		
10	10	DEC APRAIL	1	13.20	0.00017	13.109							0.00	0.00		
11	11	HENC:	1	0.48	1.00000	0.400	-2.34	140.00	65.00	140.00	155.21		0.00	0.00		
12	12	GR YFAM	1	15.20	0.999990	13,199	+5.64						0.00	0.00		
131	13	6.8		3.45	0.99990	5.450	1.64	35.00	10.00				0.00	6.00		
14	54	GH.0G	8.1	0.29	1.00000	0.277	25.37			20.00	10.00		0.00	0.00		
15	15	OPL SPARE	¥.	15.20	0.04467	13.157	-5.87						0.00	0.00		
16	16	COL.	1	0.48	0.99925	0.400	-5.67	35.00	17.00				0.00	0.00		
17	. 17	BEL BG	1	0.28	1.00000	9.277	28.35			35.00	75.07		0.00	0.00		
1.0	18	MCCOURT APA	1	15.20	0.99051	13,150	18.58						0.00	6.00		
111	10	MCCLIRE	1	0.40	0.09093	5.479	-1.56	125.00	65.00				0.00	0.00		
201	20	NCCLURE BG	1	6.28	1.00000	0.377	100.55			125.00	106.95		0.00	0.00		

d. Shed the MCCLURE load



enter.	Adianced y	(ani			×1		W /	ind., Remove	Quid filter *								
	Number	Name	41	a Name	Non XV	PUVolt	Velt (KS)	Angle (Degl	Load MV	Load Mar	Gen MW	Gen Mar	Switched Shorts Mar	Act G Shurt MW	Act 8 Shunt Mvar	Ares Num	Zone Num
1		SOLAR BACK	U 1		11.22	1.00000	t3.200	-30.67			792.52	\$21.50		0.00	0.00	1	
- 2		Any Mes	pi 1		0.48	6.94482	0.478	-1.02						0.00	0.00	1	
	1	Wells transf	1.1		13.20	0.91124	12.028	1.75						0.00	0.00		
6		Wells	1		2,40	0.90549	2,174	1,27	700.00	500.00				0.00	0.00	1	
- 5	3	Campus 13.	K1		13.28	0.99615	12.178	1.47	645.00	312.35				0.00	0.00	1	
- 6		Dean Plant	1		0.46	1.00000	0.480	-31.10	180.00	87.00	\$25.00	270.53		0.00	0.00		
7	-	CUR 1/1/M			13.20	6.99645	13,179	-1.47						0.00	0.50	1	
8	1	CHA	1		0.48	0.99736	0.479	.1.47	560.00	271.00				0.00	0.00	1	
- 9	1	CHR 65	1		0.28	1.00000	0.277	-51.35			580.00	215.85		0.00	0.00	1	
. 10	0	A LOCAL CONTRACT			13.20	0.09913	12.143	-1.95						0.00	0.00	1	
57	1	IRC .	1		0.48	1.00000	0.400	2.44	140.00	65.00	140.00	152.94		0.00	0.00		
- 12	1	SR WHE	1		13.20	4.99875	12,183	4.80						0.00	0.00		
13	1	164			0.45	0.99932	0.430	-1.00	20.00	10.00				0.00	0.00	1	
- 54	5	GR BG	1		-6.78	1.00000	0.217	28.21			20.00	67.73		0.00	0.00		
- 55	5	BELSPAR.	1		13.20	8.89872	15.183	-1.78						0.00	0.00		
1.74	5	1 181	1		5.41	6.99925	0.400	:1.78	35.00	17.00				0.00	0.00		
17	T.	00.05	1		0.28	1.00000	0.277	28.34			15.00	72.56		0.00	0.00		
18	5	MCCLURE II	16.1		13.20	0.99935	\$3,191	-1.66						0.00	0.00	1	
19	1	MCCCURE	1		2.43	6.99935	0.400	-1.68	125.00	65.00				0.00	0.00	1	
20	2	MCCLURE &	11		0.28	1.00000	0.277	-51.50			125.00	\$5.20		0.00	0.00		

3.

Name	Area Name	Nom kV	PU Volt	Volt (kV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
CNR									
Campus	13.2k 1		13.20 0	.99826	13.177	-1.31	645.00	312.38	
GJL									
Campus	13.2K 1		13.20 0	.99810	13,175	-1.34	645.00	312.38	
BEL									
Campus	13.2k 1		13.20 0	.99811	13.175	-1.46	645.00	312.38	
MCCLU	RE								
Campus	13.2k 1		13.20 0	.99818	13.176	-1.47	645.00	312.38	

After comparing, the whole system is most stable when I chose to shed the CNR. Because the voltage of campus is closest to 13.2kV when we choose to shed the CNR.

	 Mie	cro-Grid Expa	nsion	Budget Fall 2019-Spring	2020		
Itoms	Cost PI I	Otv		Total		-	
SEL-451-5 (Generator Synchronizer)	\$ 5,615.00	1	\$	5,615.00	Total Cost:	\$	37,344.24
SEL-3555 (RTAC)	\$ 7,195.00	1	\$	7,195.00			
SEL-751 (Relay)	\$ 990.00	8	\$	7,920.00	Cost of Risk Insurance	\$	373.44
2 AWG Cable	\$ 1.21	10200	\$	12,342.00			
1 in 40 conduit	\$ 4.15	1020	\$	4,233.00	Total Cost w/ Tax:	\$	39,958.34
1 in 80 conduit	\$ 6.54	6	\$	39.24			
2 in 40 conduit	\$ 8.31	0	\$	a 31	Total Cost w/ Tax and w/ 15%	\$	45,952.09
2 in 80 conduit	\$ 15.70	0	\$	-			
					Total Cost during project:	\$	100.00
EXPO Poster	\$ 100.00	1	\$	100.00			

Budget Summary

This budget is taken as the constant costs, such as the price of cable per foot that needs to be run underground within the 1-inch conduit. Due to code standards 40 conduit can be run underground, but 80 must be run above ground. Most of the conduit will be run within the steam tunnels but for what isn't it will be a variable cost. What makes it a variable cost will be the cost of labor, cost of equipment, as well as how many feet will need to be dug up to code standards. The other main variable cost consists of what type of landscaping and concrete work will need to be done. On the right side of the sheet above you have the total fixed costs, with your cost of risk insurance being 1% of the total fixed costs. The total cost was also adjusted with taxes as well as inflation of up to 15% to give a more accurate representation. The only cost during this project consisted of the EXPO poster.

Recommendations

There are several facets of this project that can be built upon for future projects. Firstly, the exact equipment locations, interconnectivity, and communications can be analyzed and optimized. Also, a team could work on doing a more in-depth analysis of the effects of daytime vs. nighttime conditions. The load shedding algorithm developed in RTDS by the "Take a Load Off" team could be integrated into Power World. Another path one could go down is to use a CT to determine the actual power factor of the building loads and determine the issues associated with the reactive power regulation and balancing within the system. Another option would be to develop a script that integrates both load shedding and seasonal (monthly and day/night) to simulate the status of the micro grid over the course of an entire year with accurate weathering data. Finally, energy storage via the use of batteries or pumping water, for example, is something a future team may want to explore to be able to harness the full potential of the solar arrays.

Appendix

Instructions to change months for Seasonal Analysis

These are the instructions to change through the different months for the seasonal analysis. This is for Powerworld 20. You will need the different .aux files that correspond to the different months.

Step 1: Open the PowerWorld file, the Power flow analysis

Step 2: Click the Solve button -> Reset to Flat Start



Step 3: Click the Script button, highlighted below



Step 4: Click the Auxiliary File -> Load Auxiliary File

🔘 Script Con	nmand Exec	ution Dialog:	Submode =	POWERFLOW	×
Auxiliary File	Quick Aux	Export Field	Names		
Execute	Execute of	on ENTER key	Abort		
I					
Chanulas					Chara
Show Log					Close

Step 5: Select the one of the month .aux files, then all the values should be changed to be from that month. Close out of the above Dialog

Step 6: Click the Run to start the Power flow analysis (Green button) or any other analysis that you want to do

