Electrical Depth

Introduction

The nature of TCES and the desire to be as efficient and green as possible led me to investigate several unique aspects of the electrical system. In many buildings, power is generated on site using a cogeneration unit, which can produce usable power as well as waste heat in the form of steam or hot water. This is much more efficient than a traditional grid energy and natural gas boiler combination. In addition, photovoltaics are becoming more common as a means to produce energy and reduce the load drawn from the grid.

The first thing I am investigating in my electrical depth is the new cogeneration system and then I will move to the photovoltaic system. From there I will move to the new lighting loads that were added as a consequence of the new design for the lobby, chemistry lab, case study classroom, and exterior. Finally, any major electrical components that are impacted, such as new panelboards, new feeders, and new equipment will be addressed and added to the riser diagram. Costs for new equipment will be analyzed within each section to which that equipment pertains. To expand the relevance of this depth study to encompass more of the architectural engineering disciplines, I will also be investigating the impact that the cogeneration unit has on the solar hot water heating and service hot water (see “Solar Hot Water Analysis” on page 73).

Design Goals

The overall goal of the electrical study is to design a fully functional system that suits the needs of the building and complies with the 2002 NEC code. Please see individual sections for each part's individualized design goals.

Design Solution

Please see individual sections for each part's individualized design solution.

Cogeneration Design

Introduction

For proper analysis of the Cogeneration system I will use the results obtained from the eQuest energy model which can be found in Appendix B-CD. Natural gas and electricity prices have been obtained from Nevada Power Company as well as rate structure data concerning cogeneration within the grid (See Appendix B-CD for rate structure details). In addition to using eQuest to analyze the system, I will use RETScreen International's Combined Heat and Power tool to determine feasibility, cost effectiveness, and greenhouse gas savings for the new cogeneration system.

Design Goals

The overall goal of this analysis is to determine the feasibility of installing (2) 30kW microturbines. This feasibility analysis attempts to determine whether this is a viable design option based on the criteria of building electrical load, payback analysis, and greenhouse gas analysis. The cogeneration units must make sense in terms of the electrical load profile generated by eQuest, as well as have a reasonable payback of less than 10 years and produce less greenhouse gases than just using the grid alone. After the analysis is completed, conclusions will be drawn as to the viability of adding a second cogeneration unit to the existing building infrastructure.

Design Solution

Due to strict emissions requirements set forth by TRPA in addition to the desire to be as “green” as possible, microturbines are determined to be the best solution. They emit far less greenhouse gases and other pollutants than internal combustion engines or diesel engines, are much less costly than fuel cells, and are much more compact than turbines. Also, they allow for the smaller sizes required by the building electrical load. As such, (2) 30kW Capstone C-30 microturbines (cutsheet located in Appendix B-CD) are used in the design. The use of (2) 30kW turbines versus (1) 60kW will allow for one turbine to be turned off at night or during periods of low electrical load while the other is running at close to peak capacity, leading to higher efficiencies for the turbines. The use of two turbines also allows for redundancy in the event that one should fail. If this happens, you will still have a working source of power even if the grid is also down.

Analysis

Building Electrical Load

The output from eQuest (which can be viewed in it's entirety in Appendix B-CD along with the eQuest input files) indicates that the electrical load on the building throughout the year varies from about 190kW to about 300kW during operating hours. Since this is the case,

(2) 30kW cogeneration units make sense since they will be able to run at full capacity throughout the day (even when considered in conjunction with 60kW of photovoltaics. See "Photovoltaic Design" on page 58 for details). However, at night with computers in stand-by mode and only a limited number of lights and other equipment operating, the load on the building will likely not exceed 30kW. Because of this fact, I decided to go with (2) 30kW units instead of a single 60kW unit so that one can be shut down at night while the other runs at, or near, peak capacity.

Abbreviated eQuest output	
Month	**Load (kW)**
January	193.2
February	204.5
March	220.0
April	268.7
May	254.7
June	255.5
July	268.1
August	244.7
September	302.6
October	236.0
November	234.0
December	196.8

Table 2.1

Payback

Using RETScreen International's CHP analysis program, I performed a cost analysis. A 25 year life was assumed, along with less than average costs for operating and maintenance due to the fact that Capstone microturbines use a proprietary magnetic bearing system that does not require the use of oil, leading to a minimal amount of physical contact between many of the moving parts. This lack of contact mean less maintenance is required, and no oil use means no oil changes and a smaller environmental impact. The additional cost of a transformer was also figured in. Because the spark gap (the difference in price between buying electricity and buying natural gas to produce electricity) is so large, the payback (table 2.2 below) is relatively quick and after 8 years TCES would see a large amount of savings on energy. Please see the spreadsheets in Appendix B-CD for more detailed information concerning the process and figures used.

Yearly Cash Flows		
Year	**Pre-tax**	**Cumulative**
#	**$**	**$**
0	(67,534)	(67,534)

Yearly Cash Flows		
1	7,318	(60,216)
2	8,211	(52,005)
3	9,130	(42,875)
4	10,077	(32,797)
5	4,097	(28,700)
6	12,057	(16,643)
7	13,092	(3,551)
8	14,158	10,607
9	15,256	25,862
10	8,323	34,185
11	39,987	74,172
12	41,186	115,358
13	42,422	157,780
14	43,695	201,474
15	35,658	237,132
16	46,356	283,487
17	47,746	331,234
18	49,179	380,412
19	50,654	431,066
20	41,337	472,403
21	53,739	526,142
22	55,351	581,492
23	57,011	638,504
24	58,722	697,226
25	47,921	745,146

Table 2.2

Greehouse Gases

Using data obtained from Electrical Power Annual concerning the make-up of how energy is produced in the United States (percent produced using coal, percent using nuclear, etc. - see table 2.3 below), the RETScreen program was again used to determine the greenhouse gas savings benefits to using the cogeneration system versus grid energy.

Fuel type	***Fuel Mix***
Natural gas	9.3%
Nuclear	22.8%
Coal	55.7%
Hydro	4.7%
Wind	4.7%
Oil (#6)	2.8%

Fuel type	***Fuel Mix***
Tot Electricity Mix	100.0%

Table 2.3

Based on the amount of CO2 produced by each method of producing electricity the amount of tons of CO2 that were saved each year was calculated to be 245 tons. This calculation does not, however, include any greenhouse gases generated during the production of the cogeneration units themselves since this is a yearly savings. A more in-depth analysis would be needed to determine the greenhouse gas payback period.

RETScreen Output

Grid GHG emissions (tCO2)	***Cogen GHG emissions (tCO2)***	***Net annual GHG reduction (tCO2)***
1,850	1,605	245

Table 2.4

Using my own spreadsheet (Appendix B-CD) and additional data taken from Electrical Power Annual I found that you save about 340 lbm of particulate matter, 4,000 lbm of SOx, 2,200 lbm of NOx, and 660,000 lbm of CO2 (299.35 tons) per year by using a cogeneration unit versus relying on the grid to supply your energy.

Data Obtained Using EPA Data

	kW	***kWh/year***	***Particulates (lbm)***	***SO2 (lbm)***	***NOx (lbm)***	***CO2 (lbm)***
Grid	60	525,600	337.93	3,964.77	2,333.53	725,487.31
Cogen	60	525,600	0.00	0.66	124.02	65,526.57
	Savings per year:		337.93	3,964.11	2,209.50	659,960.74

Table x.5

Conclusions

The installation of (2) 30kW microturbines is highly recommended based on the information gathered. Given the 25 year project life, the 5 year payback is acceptable, and falls within the criteria set forth before the analysis began. When combined with the additional savings of 245 to 299 tons of greenhouse gases (depending on the analysis method involved) and the ability to be less reliant on the grid for energy, it is apparent that adding the additional cogeneration unit for a total capacity of 60kW is a practical and beneficial way to obtain energy.

Photovoltaic Design

Introduction

In the following photovoltaic analysis results from the eQuest energy model are used in conjunction with the RETScreen photovoltaic analysis tool to obtain data concerning the viability of increasing the photovoltaics from 30kW to 60kW. Pricing data for the photovoltaic modules as well as the inverters is obtained from the module manufacturer, Connect Energy. The photovoltaics used are thin-film, flexible units that are thermally bonded directly to the roof, so balance of systems is assumed to be minimal from an equipment and cost perspective. Pricing for purchased energy as well as rate structuring concerning photovoltaic systems is obtained from Nevada Power. RETScreen International's photovoltaic tool is used to determine feasibility, cost effectiveness, and greenhouse gas savings for the revised photovoltaic system.

Design Goals

The primary goal in this analysis is to determine the feasibility of installing a photovoltaic array of 60kW versus an array of 30kW. General criteria used in the analysis are payback time, LEED benefits, greenhouse gas benefits, and electrical load of the building. More specifically, a reasonable payback time of 10 years or less (even though preliminary analysis shows this to be nearly impossible) is hoped for. Also, the cost to benefit ratio of an additional LEED point added to the project scorecard (Credit 2.3 – Renewable Energy, 20% Contribution. See “LEED Analysis” on page 70 for more details) is investigated to discover if the additional LEED point is worth the added cost. Throughout all of this, the photovoltaic system must also make sense in terms of the electrical load profile of the building as determined by the eQuest energy model. In addition to these goals the system must be able to support a snow load of 200 lb/sf. After the analysis is performed, conclusions will be drawn as to the viability of the new photovoltaic system.

Design Solution

The decision to investigate whether 60kW of installed photovoltaics is a viable option was driven by the LEED credits concerning renewable energy production. Producing 60kW of power would mean that 20% of the building's load is generated using renewable resources (see table 2.7 below). This would result in an additional LEED point being gained. Another expected benefit of this would be a lower monthly utility bill and a reduction in greenhouse gases and pollutants. The photovoltaic modules used are model SP480 from Solar Roofing Systems, Inc. (a subsidiary of Connect Energy) and were chosen for their high snow-load rating and high efficiency. The modules are flat, flexible, and are thermally bonded directly to the roof, leading to a lower cost for the balance of systems. A problem arises, however, when deciding where to put the modules. There is enough additional roof space on the south facade to add the modules, but the orientation of the roof is not always directly south due to sloping peaks, meaning that the output of the modules would be affected. This has been accounted for in the efficiency of the modules. See illustration 2.6 for proposed location.

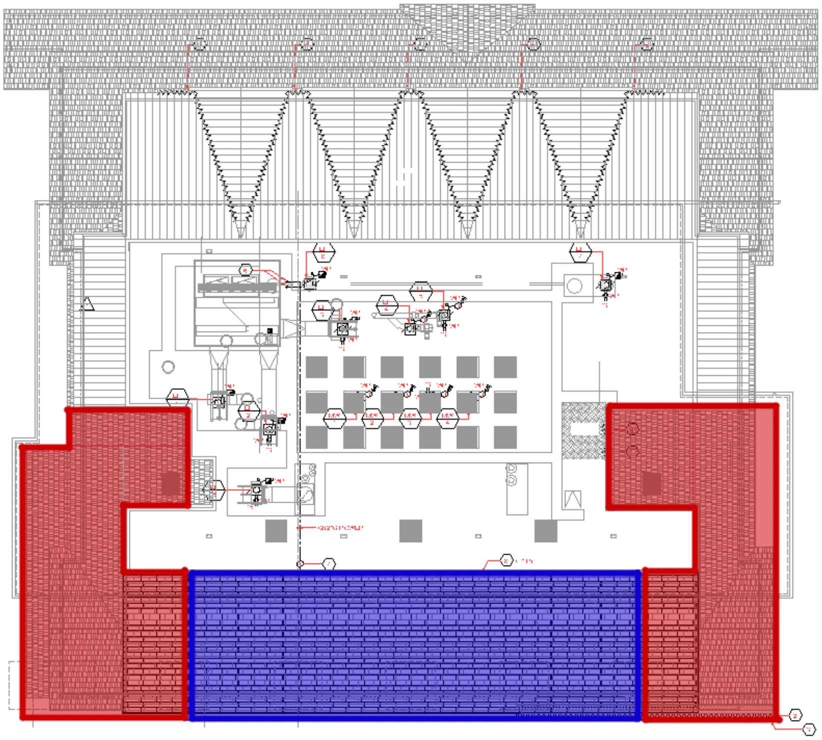


Figure 2.6 - Blue = existing, Red = Proposed addition

Analysis

Building Electrical Load

The output from eQuest (which can be viewed in it's entirety in Appendix B-CD along with the eQuest input files) indicates that the electrical load on the building throughout the year varies from about 190kW to about 300kW during operating hours. This leads to the conclusion that during the day the 60kW of photovoltaics will be used effectively (even when considered with 60kW of cogeneration).

Abbreviated eQuest output	
Month	**Load (kW)**
January	193.2
February	204.5
March	220.0
April	268.7
May	254.7

Abbreviated eQuest output	
June	255.5
July	268.1
August	244.7
September	302.6
October	236.0
November	234.0
December	196.8

Table 2.7

The daytime load is large enough to consume all the power generated by the photovoltaic system and the building electrical load at night can be taken care of by a cogeneration unit, so a battery system is judged to be unnecessary, eliminating a sizable portion of the up front cost of system. The ability to store power during periods of low power consumption during the day was weighed against the price of including such a feature, and the batteries were found to not make sense from a cost-benefit stance. An additional inverter is necessary to handle the added load, which is assumed to be replaced every 15 years, and an additional panelboard must be added to connect the photovoltaics to the building's grid.

Payback

RETScreen's photovoltaic analysis tool was used to conduct a basic cost analysis of the new system. A project life of 25 years was assumed along with a 15 year replacement period for the inverters. A price of $8,000 per installed kilowatt of photovoltaics and $500 per kilowatt for the inverter are used, both of which were confirmed by several industry sources including a representative from Connect Energy. Also considered was the fact that Nevada Power allows a rebate of up to 1/3 of the cost of the modules and installation ($2666.67 per installed kilowatt) and a 5 year accelerated tax depreciation rate. RS Means is used to determine the cost of an additional 100A, 3 phase panel. The payback period is 24 years (see table 2.8 below), which does not meet the goals of having a payback period of under 10 years. Realistically, the photovoltaics were never expected to pay for themselves within the life of the project. For a more detailed view of the calculations please see Appendix B-CD.

Yearly Cash Flows		
Year	**Yearly**	**Cumulative**
#	**$**	**$**
0	(239,936)	(239,936)
1	4,514	(235,422)
2	4,977	(230,445)
3	5,462	(224,983)
4	5,969	(219,014)
5	6,499	(212,515)
6	7,053	(205,462)

Yearly Cash Flows		
7	7,633	(197,828)
8	8,240	(189,589)
9	8,874	(180,715)
10	9,538	(171,177)
11	10,232	(160,945)
12	10,959	(149,985)
13	11,720	(138,266)
14	12,516	(125,750)
15	(30,100)	(155,850)
16	14,221	(141,629)
17	15,134	(126,495)
18	16,090	(110,405)
19	17,091	(93,314)
20	18,139	(75,176)
21	19,236	(55,940)
22	20,385	(35,555)
23	21,589	(13,966)
24	22,849	8,883
25	24,169	33,052

Table 2.8

Greenhouse Gases

Using data obtained from Electrical Power Annual concerning the make-up of how energy is produced in the United States (percent produced using coal, percent using nuclear, etc. - see table 2.9 below), the RETScreen program was again used to determine the greenhouse gas savings benefits to using the cogeneration system versus grid energy.

Fuel type	***Fuel Mix***
Natural gas	9.3%
Nuclear	22.8%
Coal	55.7%
Hydro	4.7%
Wind	4.7%
Oil (#6)	2.8%
Tot Electricity Mix	100.0%

Table 2.9

Based on the amount of CO2 produced by each method of producing electricity the amount of tons of CO2 that were saved each year was calculated to be about 71 tons. This calculation does not, however, include any greenhouse gases generated during the production of the modules themselves since this is a yearly savings. A more in-depth analysis would be needed to determine the greenhouse gas payback period.

RETScreen Output		
Grid GHG emissions (tCO2)	***PV GHG emissions (tCO2)***	***Net annual GHG reduction (tCO2)***
71.02	0	71.2

Table 2.10

LEED Credit

Credit EA2.3 in the LEED 2.1 rating system states that a credit can be gained by providing 20% of the building's energy from renewable sources, of which photovoltaics falls into this category. Based on the eQuest energy model, 60kW of photovoltaics will equate to 20% of the building energy load and cost (which maxes out around 300kW, but for much of the year is below that). This would guarantee the project another LEED point, giving a slightly higher probability of gaining the LEED platinum rating that the owner desires in case some points are lost.

Snow Load

Due to a high snow load in the Lake Tahoe area (around 200lb/sf), many photovoltaic panels cannot be used as they have glass covers that will not hold up under such loads. As such, I sought out a system of completely flat, cover-less photovoltaics that would be able to withstand such loads. Both the CE-tiles and the SP480 tiles manufactured by Connect Energy would work, but in the end I went with the SP480 tiles due to their flat, flexible, and lightweight nature (they weigh only 2.5lbs per square foot). Please see the cutsheet in Appendix B-CD for more information.

Conclusions

The decision of whether or not to install 60kW of photovoltaics is not very cut and dry. The advantages of reducing greenhouse gas production, an additional LEED point and coexisting well with the building's electrical load must be weighed against the large upfront cost and long payback period of the modules. Because of the fact that the owner has put a large emphasis on gaining a LEED platinum rating, and the strong desire to be as sustainable as possible, I recommend installing the 60kW photovoltaics. The benefits, in this case, outweigh the costs.

Electrical System Design

Introduction

The main impacts on the electrical system are from the cogeneration units (see “Cogeneration System” on page 54), the photovoltaics (see “Photovoltaic System” on page 58), and from the fixtures that were chosen for the four rooms studied (see “Lighting Depth” on page 7 for details). Panels are redesigned for the added equipment, and the riser diagram is investigated to provide feeders and space for the photovoltaics and cogeneration.

Design Goals

The main goal of this analysis is to design a functional, logical system that complies with the NEC 2002 code. The addition of a panelboard to accommodate the photovoltaics will require the sizing of a new feeder, which must be large enough to handle the amperage of the system. The cogeneration system feeds directly into the main switchboard, so an appropriately sized breaker and feeder must be designed. In addition, space must be found for the new lighting equipment on the existing panelboards.

Design Solution

The existing switchboard contains space to connect the cogeneration unit in addition to space for the new photovoltaic panel. The cogeneration unit must be connected via a 30kW transformer due to the fact that it produces 480/277V instead of the needed 120/208V. The photovoltaics also require an inverter and combiner boxes to gather all the arrays together. All of the equipment is connected via appropriately sized wire based on the NEC 2002 requirements, and is protected by the necessary overcurrent devices as determined using the NEC 2002 code as well. Lighting loads were all below the original design loads, so no panels needed to be resized, however individual lighting circuits were checked to ensure they were using appropriately sized wires and the correct size breakers.

Analysis

Single Line Diagram

For size and readability reasons, a printed copy of the single line diagram is not included. Please see the electronic version on the CD in Appendix B-CD.

Feeders

Each cogeneration unit produces 30kW, which assuming a 90% power factor yields:

$$30\text{kW}/.9 = 33.33\text{kVA}$$

cogeneration side: 33.33kVA / (277V *3) = 40.11A
switchboard side: 33.33kVA / (120V *3) = 92.58A

Because the cogeneration system is intended to be run constantly, a 1.25 multiplying factor is used.

cogeneration side: 40.11A * 1.25 = 50A
switchboard side: 92.58 * 1.25 = 116A

This means that on the cogeneration side of the transformer, the feeder must be sized for 50A, and on the switchboard side it must be designed for 116A. Wire ampacity ratings and sizes are obtained from table 310.16 of the NEC 2002 code.

50A – cogeneration side: (3) #6 + (1) #8 G.
116A – switchboard side: (4) 1/0 + (1) #6 G.

In addition, a 125A circuit breaker is needed when connecting the feeder to the switchboard.

Each photovoltaic panel will also be connected to 30kW at 208/120V and a 90% power factor is again assumed. This yields:

30kW/.9 = 33.33kVA
33.33kVA / (120V * 3) = 92.58A

Because the photovoltaic system is intended to be run constantly, a 1.25 multiplying factor is used.

92.58A * 1.25 = 116A

Thus, the feeder for the photovoltaic panel must be sized for 116A, as must the circuit breaker for the panelboard itself. Using wire ampacity ratings and sizes obtained from table 310.16 of the NEC 2002 code.

Panels PV1 and PV2: (4) 1/0 + (1) #6 G.

In addition, a 125A circuit breaker is needed to protect the panels.

Branch Circuits

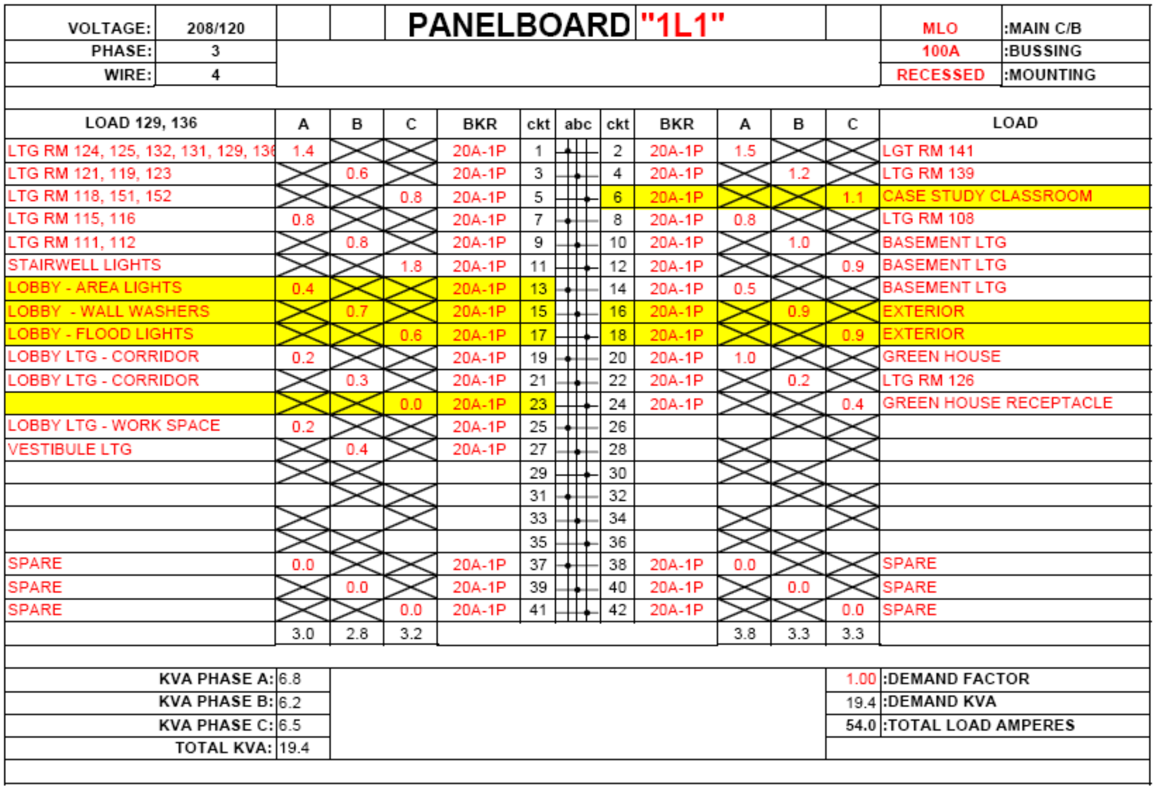
Lighting

It is desirable to put all lighting on #12 AWG wire and protect them with 20A circuit breakers since this is the most common design practice, which will likely lead to cheaper costs.

The gauge of wire chosen must be derated to 16A, and it is hoped that 12A will not be exceeded on each circuit for expansion and addition reasons. The summary of each circuit can be found in table 2.11 below, and the panelboards can be found in figures 2.12 and 2.13. For the physical locations of lighting panelboards, please see the section entitled “Lighting Depth” on page 7.

Panel	*Ckt #*	*Description*	*Amps*	*Wire Size/Breaker*
1L1	13	Lobby – Area Lights	5.94A	(2) #12 – 20A
1L1	15	Lobby - Wallwashers	4.32A	(2) #12 – 20A
1L1	17	Lobby - Floodlights	3A	(2) #12 – 20A
1L1	6	Case Study Classroom	9.17A	(2) #12 – 20A
1L1	16	Exterior	7.75A	(2) #12 – 20A
1L1	18	Exterior	7.75A	(2) #12 – 20A
2L1	4	Chemistry Lab	8.64A	(2) #12 – 20A

Table 2.11



VOLTAGE: 208/120
PHASE: 3
WIRE: 4

PANELBOARD "1L1"

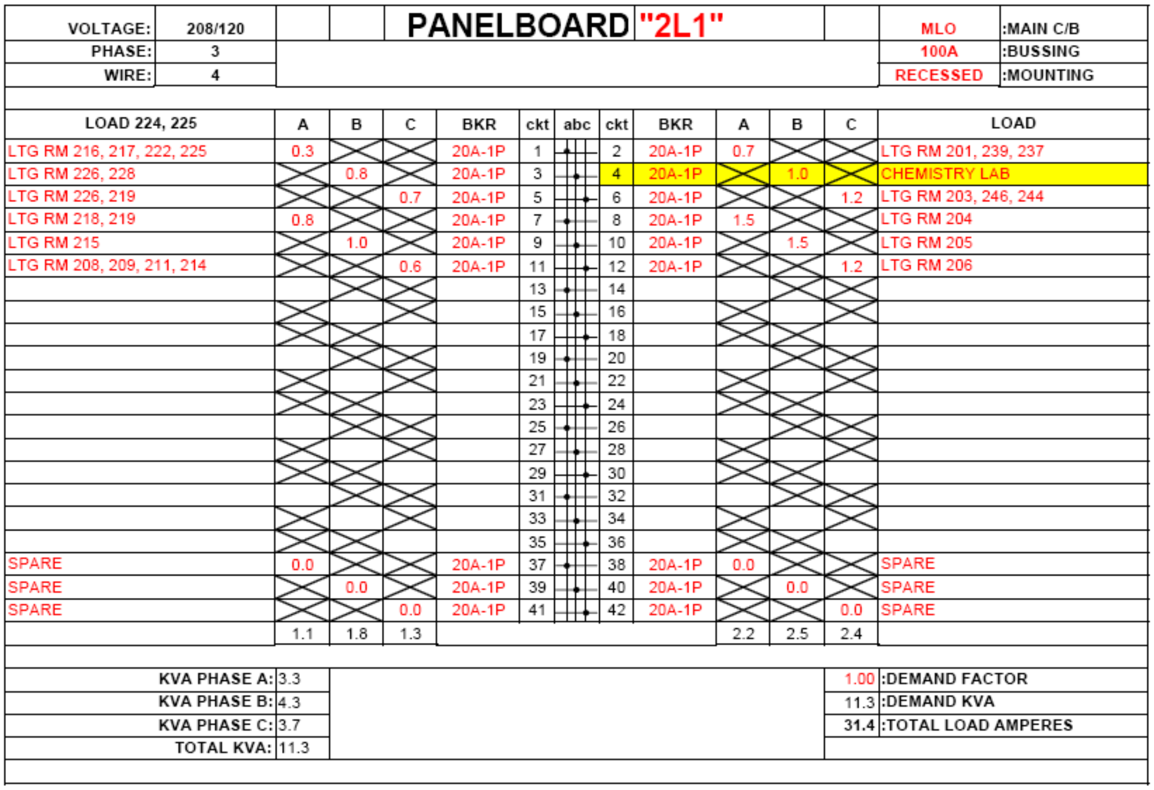
MLO :MAIN C/B
100A :BUSSING
RECESSED :MOUNTING

LOAD 129, 136	A	B	C	BKR	ckt	abc	ckt	BKR	A	B	C	LOAD
LTG RM 124, 125, 132, 131, 129, 136	1.4			20A-1P	1		2	20A-1P	1.5			LGT RM 141
LTG RM 121, 119, 123		0.6		20A-1P	3		4	20A-1P		1.2		LTG RM 139
LTG RM 118, 151, 152			0.8	20A-1P	5		6	20A-1P			1.1	CASE STUDY CLASSROOM
LTG RM 115, 116	0.8			20A-1P	7		8	20A-1P	0.8			LTG RM 108
LTG RM 111, 112		0.8		20A-1P	9		10	20A-1P		1.0		BASEMENT LTG
STAIRWELL LIGHTS			1.8	20A-1P	11		12	20A-1P			0.9	BASEMENT LTG
LOBBY - AREA LIGHTS	0.4			20A-1P	13		14	20A-1P	0.5			BASEMENT LTG
LOBBY - WALL WASHERS		0.7		20A-1P	15		16	20A-1P		0.9		EXTERIOR
LOBBY - FLOOD LIGHTS			0.6	20A-1P	17		18	20A-1P			0.9	EXTERIOR
LOBBY LTG - CORRIDOR	0.2			20A-1P	19		20	20A-1P	1.0			GREEN HOUSE
LOBBY LTG - CORRIDOR		0.3		20A-1P	21		22	20A-1P		0.2		LTG RM 126
			0.0	20A-1P	23		24	20A-1P			0.4	GREEN HOUSE RECEPTACLE
LOBBY LTG - WORK SPACE	0.2			20A-1P	25		26					
VESTIBULE LTG		0.4		20A-1P	27		28					
					29		30					
					31		32					
					33		34					
					35		36					
SPARE	0.0			20A-1P	37		38	20A-1P	0.0			SPARE
SPARE		0.0		20A-1P	39		40	20A-1P		0.0		SPARE
SPARE			0.0	20A-1P	41		42	20A-1P			0.0	SPARE
	3.0	2.8	3.2						3.8	3.3	3.3	

KVA PHASE A: 6.8
KVA PHASE B: 6.2
KVA PHASE C: 6.5
TOTAL KVA: 19.4

1.00 :DEMAND FACTOR
19.4 :DEMAND KVA
54.0 :TOTAL LOAD AMPERES

Figure 2.12



				PANELBOARD "2L1"					
VOLTAGE:	208/120							MLO	:MAIN C/B
PHASE:	3							100A	:BUSSING
WIRE:	4							RECESSED	:MOUNTING

LOAD 224, 225	A	B	C	BKR	ckt	abc	ckt	BKR	A	B	C	LOAD
LTG RM 216, 217, 222, 225	0.3			20A-1P	1		2	20A-1P	0.7			LTG RM 201, 239, 237
LTG RM 226, 228		0.8		20A-1P	3		4	20A-1P		1.0		CHEMISTRY LAB
LTG RM 226, 219			0.7	20A-1P	5		6	20A-1P			1.2	LTG RM 203, 246, 244
LTG RM 218, 219	0.8			20A-1P	7		8	20A-1P	1.5			LTG RM 204
LTG RM 215		1.0		20A-1P	9		10	20A-1P		1.5		LTG RM 205
LTG RM 208, 209, 211, 214			0.6	20A-1P	11		12	20A-1P			1.2	LTG RM 206
					13		14					
					15		16					
					17		18					
					19		20					
					21		22					
					23		24					
					25		26					
					27		28					
					29		30					
					31		32					
					33		34					
					35		36					
SPARE	0.0			20A-1P	37		38	20A-1P	0.0			SPARE
SPARE		0.0		20A-1P	39		40	20A-1P		0.0		SPARE
SPARE			0.0	20A-1P	41		42	20A-1P			0.0	SPARE
	1.1	1.8	1.3						2.2	2.5	2.4	

KVA PHASE A:	3.3	1.00	:DEMAND FACTOR
KVA PHASE B:	4.3	11.3	:DEMAND KVA
KVA PHASE C:	3.7	31.4	:TOTAL LOAD AMPERES
TOTAL KVA:	11.3		

Figure 2.13

Photovoltaics

As with the lighting, is would be desirable to put the loads from the photovoltaics on #12 AWG wire and protect them with 20A circuit breakers. Since expansion of the photovoltaic system is not very likely, leaving room on each circuit for expansion is not as high a priority as it was for the lighting. Since all of the circuits on the photovoltaic panels are the same, only one circuit was analyzed (see table 2.14 below). For the complete panelboard layouts, see figures 2.15 and 2.16 below, and for locations of panelboards and inverters see figure 2.17.

Panel	***Ckt #***	***Description***	***Amps***	***Wire Size/Breaker***
PV1	1	PV Modules	14.2A	(2) #12 – 20A

Table 2.14

PANELBOARD "PV1"

VOLTAGE:	208/120	125A/3P	:MAIN C/B
PHASE:	3	125A	:BUSSING
WIRE:	4	SURFACE	:MOUNTING

LOAD	A	B	C	BKR	ckt	abc	ckt	BKR	A	B	C	LOAD
PV TILES	1.7			20A-2P	1		2	20A-2P	1.7			PV TILES
		1.7			3		4			1.7		
PV TILES			1.7	20A-2P	5		6	20A-2P			1.7	PV TILES
	1.7				7		8		1.7			
PV TILES		1.7		20A-2P	9		10	20A-2P		1.7		PV TILES
			1.7		11		12				1.7	
PV TILES	1.7			20A-2P	13		14					
		1.7			15		16					
PV TILES			1.7	20A-2P	17		18					
	1.7				19		20					
PV TILES		1.7		20A-2P	21		22					
			1.7		23		24					
					25		26					
					27		28					
					29		30					
	6.8	6.8	6.8						3.4	3.4	3.4	

KVA PHASE A:	10.2	1.00	:DEMAND FACTOR
KVA PHASE B:	10.2	30.6	:DEMAND KVA
KVA PHASE C:	10.2	85.0	:TOTAL LOAD AMPERES
TOTAL KVA:	30.6		

Figure 2.15

PANELBOARD "PV2"

VOLTAGE:	208/120	125A/3P	:MAIN C/B
PHASE:	3	125A	:BUSSING
WIRE:	4	SURFACE	:MOUNTING

LOAD	A	B	C	BKR	ckt	abc	ckt	BKR	A	B	C	LOAD
PV TILES	1.7			20A-2P	1		2	20A-2P	1.7			PV TILES
		1.7			3		4			1.7		
PV TILES			1.7	20A-2P	5		6	20A-2P			1.7	PV TILES
	1.7				7		8		1.7			
PV TILES		1.7		20A-2P	9		10	20A-2P		1.7		PV TILES
			1.7		11		12				1.7	
PV TILES	1.7			20A-2P	13		14					
		1.7			15		16					
PV TILES			1.7	20A-2P	17		18					
	1.7				19		20					
PV TILES		1.7		20A-2P	21		22					
			1.7		23		24					
					25		26					
					27		28					
					29		30					
	6.8	6.8	6.8						3.4	3.4	3.4	

KVA PHASE A:	10.2	1.00	:DEMAND FACTOR
KVA PHASE B:	10.2	30.6	:DEMAND KVA
KVA PHASE C:	10.2	85.0	:TOTAL LOAD AMPERES
TOTAL KVA:	30.6		

Figure 2.16

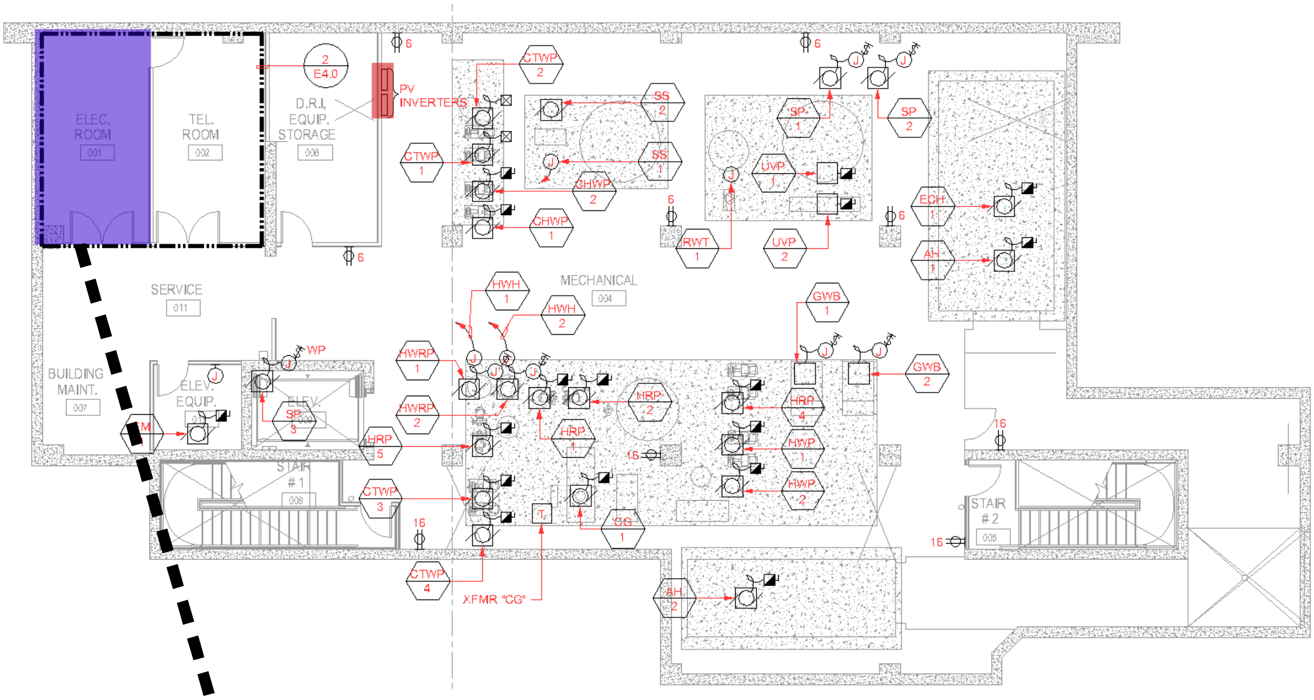
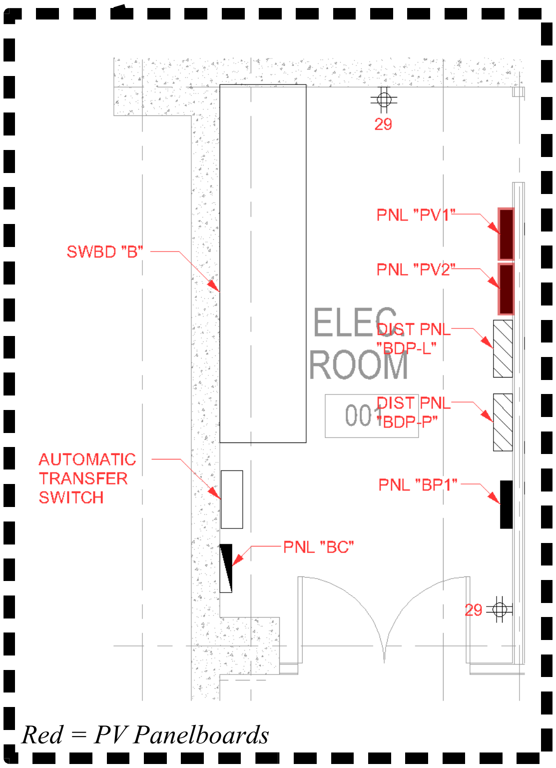


Figure 2.17 – Red = Inverter Locations, Blue = Elec. Room



Red = PV Panelboards

Conclusions

After careful review of the design documents, all the systems are functional and comply with the NEC code requirements. The equipment added is factored into the individual cost analysis performed and every effort was made to ensure that the proper equipment was chosen to complete a fully functioning system. Please refer to the “Cogeneration Analysis” on page 54 and the “Photovoltaic Analysis” on page 58 for more detailed conclusions for those systems, in addition, more in depth information pertaining to the lighting system can be found in the “Lighting Depth” section on page 7.