ELECTRICAL DEPTH INTRODUCTION

The electric utility company, Pennsylvania Power and Light (PPL), provides a 12.47 KV service from an overhead power line via underground concrete-encased conduit to an underground vault just outside of the building. In this vault, a PPL-provided transformer steps the voltage down to 480Y/277V for use within the building. Through another concrete-encased conduit, power enters the building in the Electrical Switchgear Room. The main switchboard is rated at 2500A and has connections to the fire pump, elevator, automatic transfer switches, motor control centers, and distribution panels. Transformers step down the voltage from several high voltage distribution panels to supply low voltage distribution panels. From these distribution panels, loads are connected to the system.

There are two voltage levels used in the building, 480Y/277 and 208Y/120. Most of the motors in the building operate at 480 V including the elevators, fans, pumps, overhead door, and chiller. The lower voltage is used for all of the lights, receptacles, wheelchair lift, coat rack, pipe tracing, audio/visual equipment, communication, and security.

Based on the redesign of the lighting systems, I have redesigned the lighting panels affected by my lighting redesign. I have also designed one of the distribution panels most affected by the lighting changes. Since this building is just as tall as the surrounding structures to the south, I did a feasibility study on a photovoltaic roof panel system. Finally, I performed a coordination study of overcurrent protective devices for a branch of the electrical distribution system.

PANELBOARD REDESIGN

I was able to reuse most of the same circuiting for the lighting systems. The panels affected by the lighting design were limited to three panels.

Circuiting Diagrams

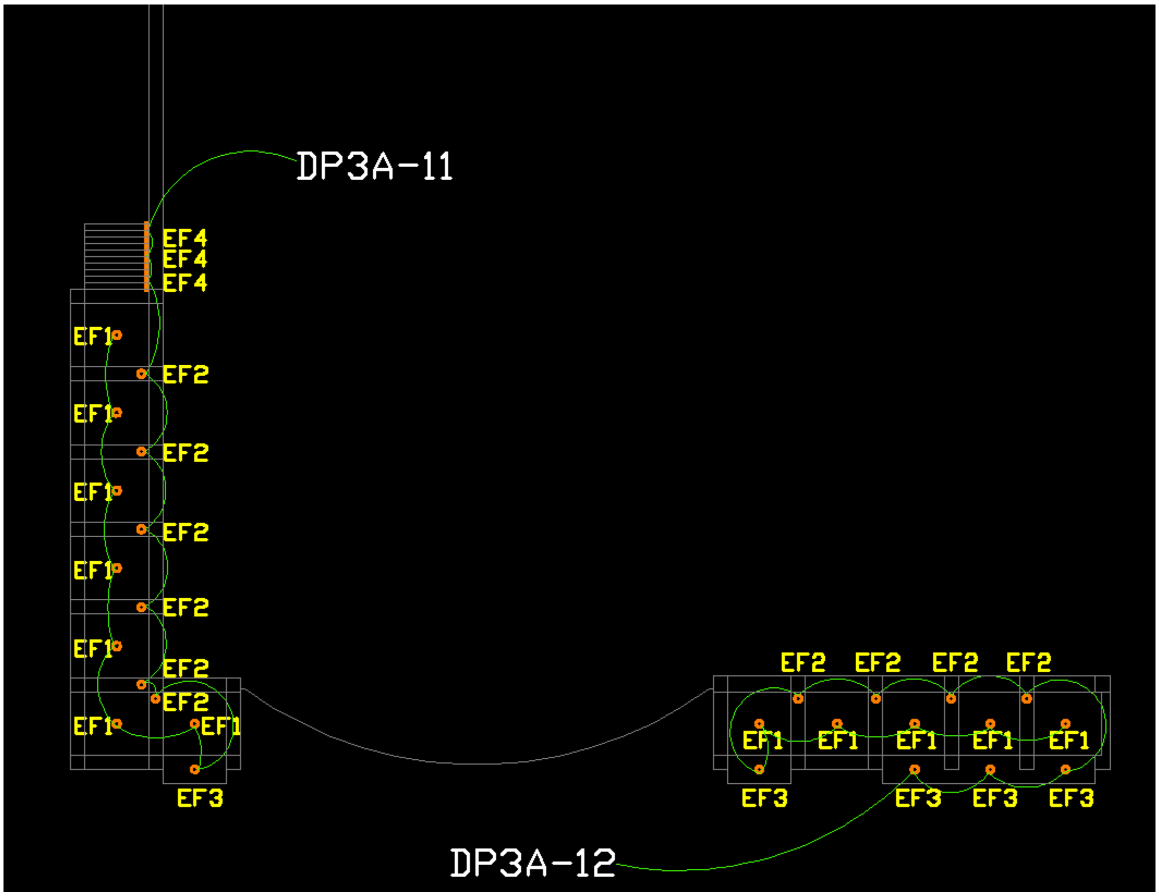

Figure 41: Building Entrance Circuiting Diagram

Figure 42: Grand Foyer First Floor Circuiting Diagram

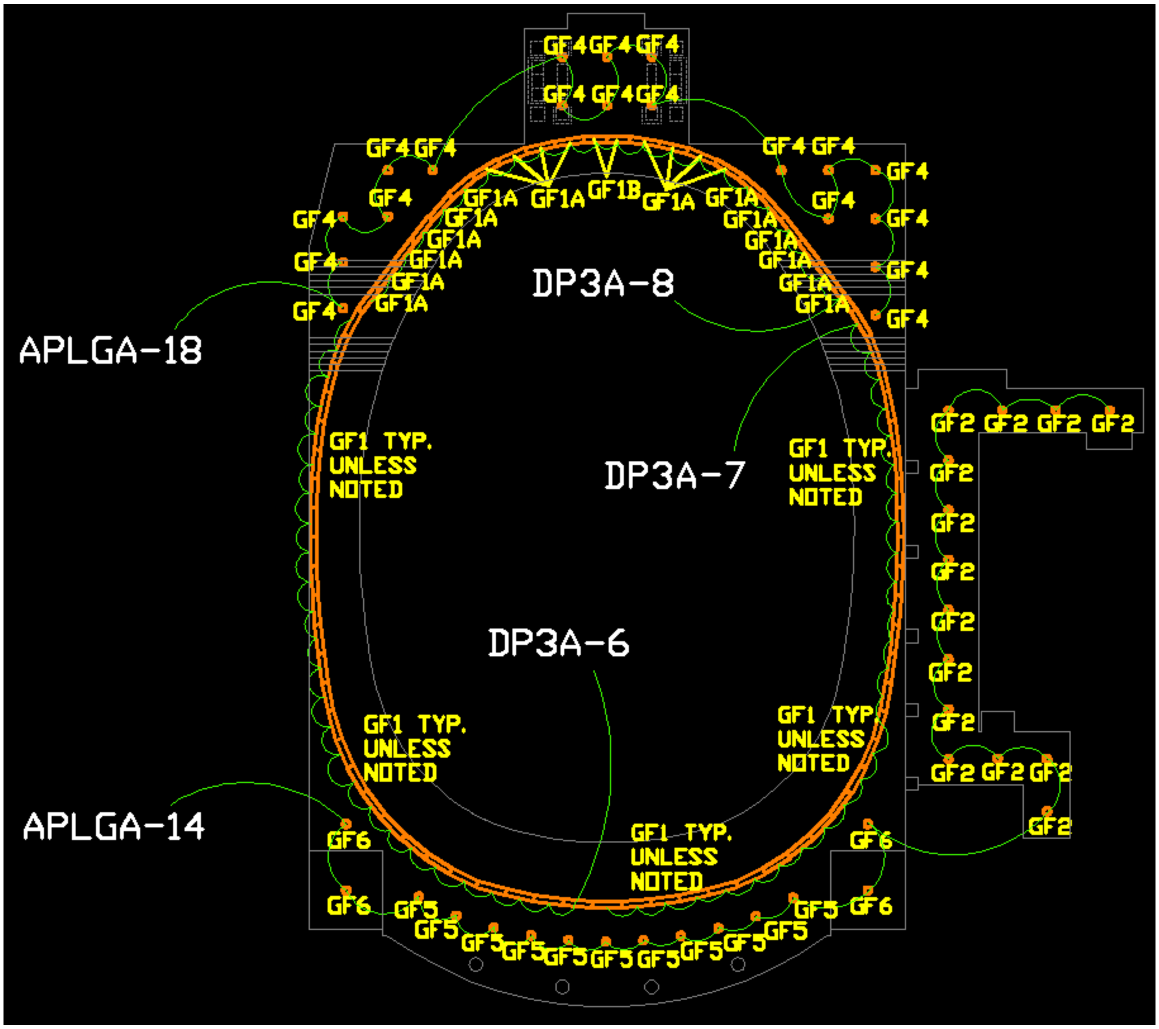

Figure 43: Grand Foyer Second Floor Circuiting Diagram

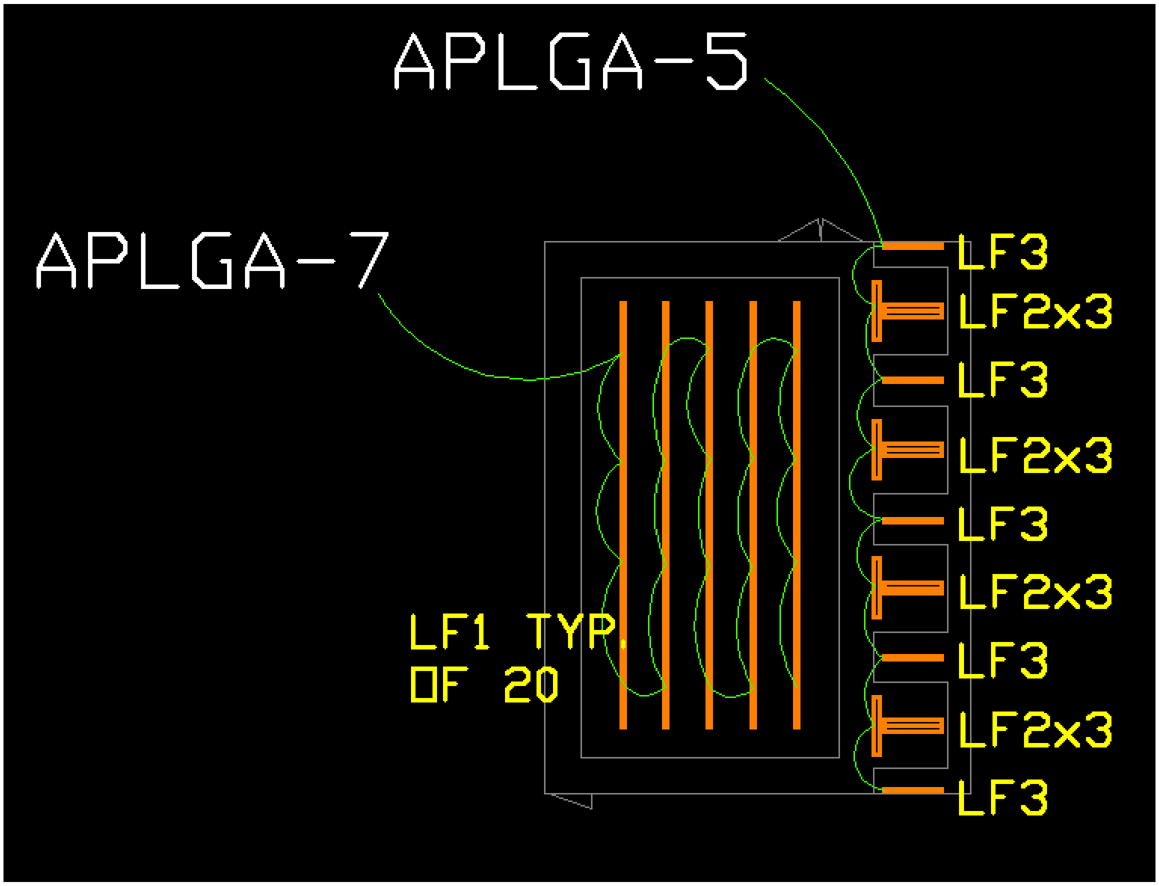

Figure 44: Library Circuiting Diagram

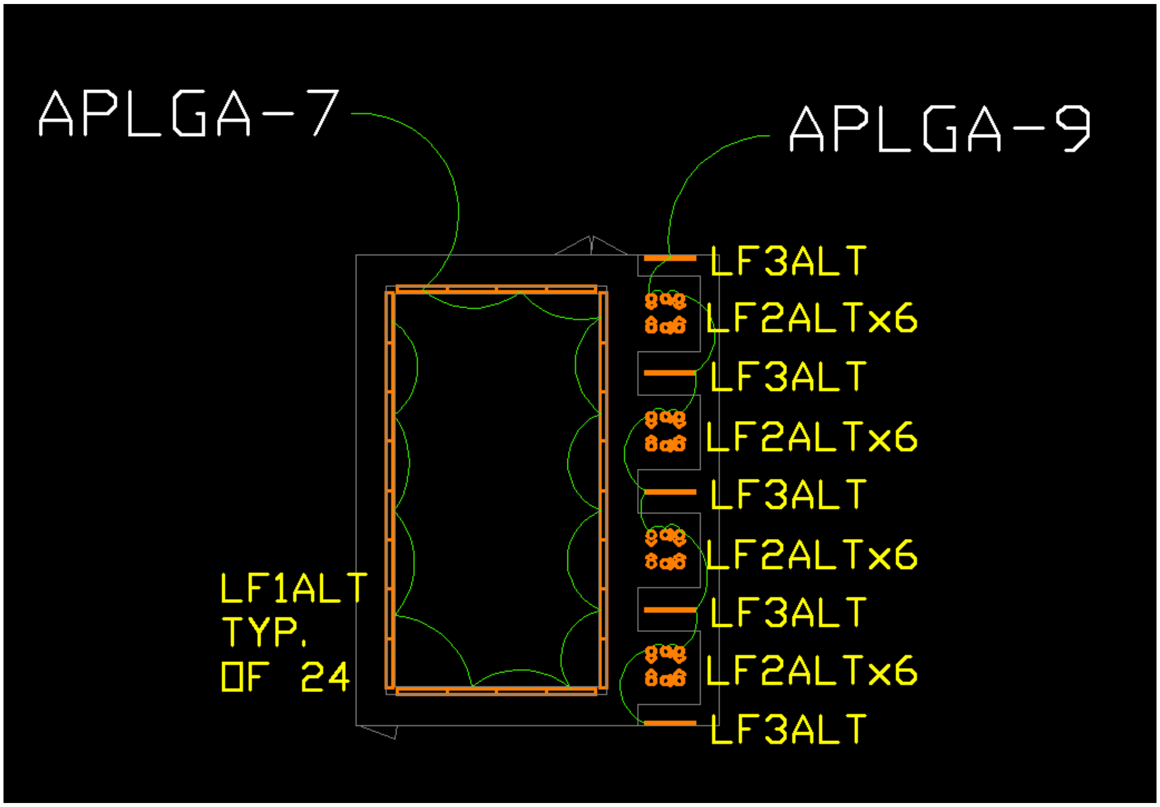

Figure 45: Library Alternate Circuiting Diagram

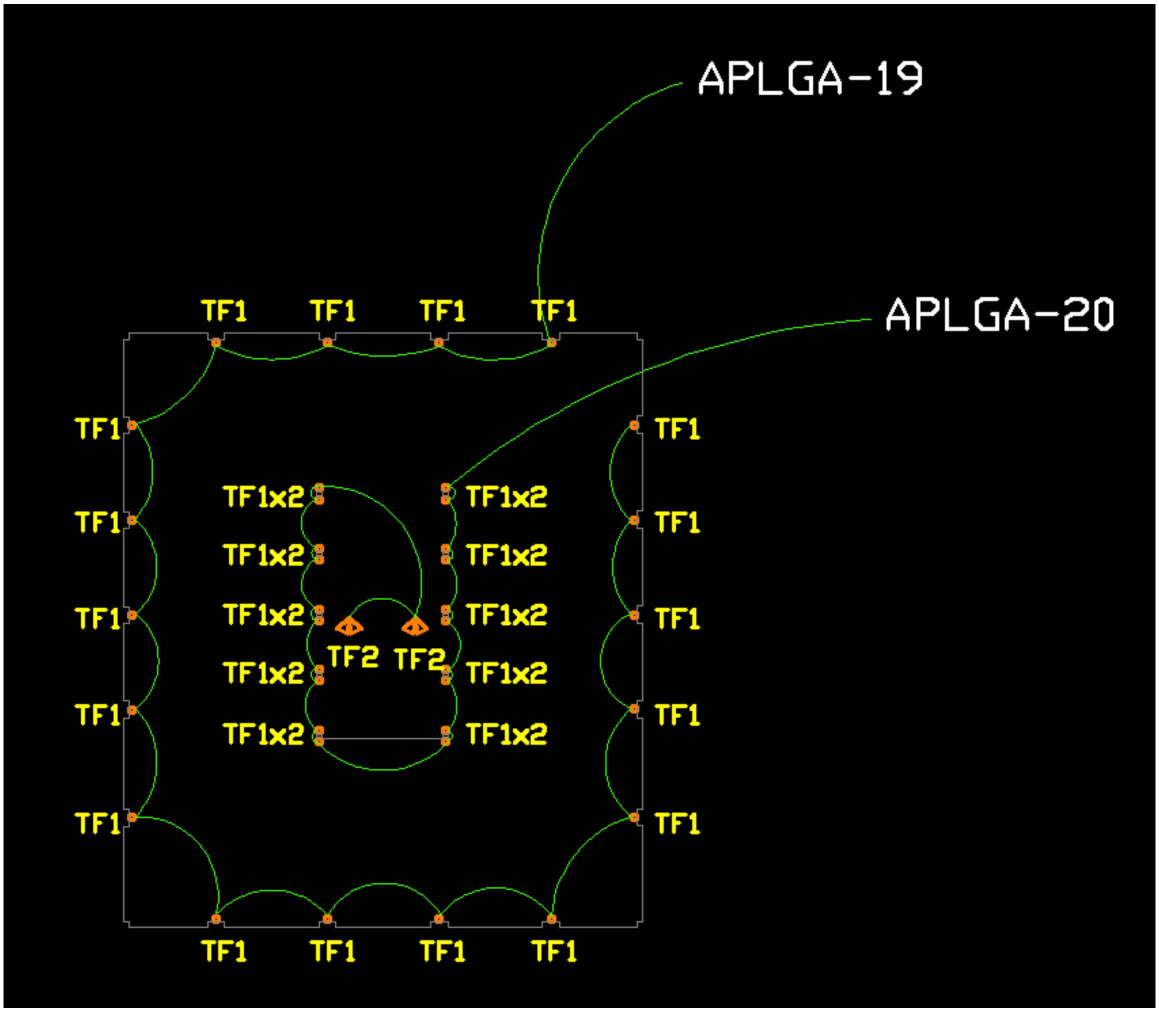

Figure 46: Roof Terrace Circuiting Diagram

Panel APELGB

Panel APELGB is an emergency panel located in the first floor electrical closet. This panel is fed by the emergency generator during power outages via a four #4AWG feeder. The original Roof Terrace lighting system was fed directly off of this panel on a timer so that the lighting system is on all night, every night. I have removed these lighting circuits from this panel and placed them on panel APLGA. Since other lighting changes could easily cause emergency lighting to be added to this panel, I have opted not to resize it based on the removal of 1500 VA.

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W SIZE/TYPE BUS: 225A SIZE/TYPE MAIN: 40A/3P C/B	PANEL TAG: APELGB PANEL LOCATION: First Floor Electrical Closet PANEL MOUNTING: SURFACE	MIN. C/B AIC: 10K OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Emergency Lighting	Lower Level	1000	20A/1P	1	*			2	20A/1P	800	Lower Level	Emergency Lighting
Emergency Lighting	Stair 4	700	20A/1P	3		*		4	20A/1P	300	Exit Signs	Emergency Lighting
Emergency Lighting	Light	600	20A/1P	5			*	6	20A/1P	1000	Exit Signs	Emergency Lighting
Emergency Lighting	2nd Floor	600	20A/1P	7	*			8	20A/1P	750	Roof Terrace	Emergency Lighting
Emergency Lighting	3rd Floor	890	20A/1P	9		*		10	20A/1P	750	Roof Terrace	Emergency Lighting
Emergency Lighting	3rd Floor	550	20A/1P	11			*	12	20A/1P	0		Spare
Spare		0	20A/1P	13	*			14	20A/1P	0		Spare
Spare		0	20A/1P	15		*		16	20A/1P	0		Spare
Spare		0	20A/1P	17			*	18	20A/1P	0		Spare
Spare		0	20A/1P	19	*			20	20A/1P	0		Spare
Spare		0	20A/1P	21		*		22	20A/1P	0		Spare
Spare		0	20A/1P	23			*	24	20A/1P	0		Spare
		0	20A/1P	25	*			26	20A/1P	0		
		0	20A/1P	27		*		28	20A/1P	0		
		0	20A/1P	29			*	30	20A/1P	0		
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A	3.15	TOTAL DESIGN LOAD (KW)	11.91
CONNECTED LOAD (KW) - B	2.64	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	2.15	TOTAL DESIGN LOAD (AMPS)	33

Figure 47: Original Panel APELGB

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W SIZE/TYPE BUS: 225A SIZE/TYPE MAIN: 40A/3P C/B	PANEL TAG: APELGB PANEL LOCATION: First Floor Electrical Closet PANEL MOUNTING: SURFACE	MIN. C/B AIC: 10K OPTIONS:

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Emergency Lighting	Lower Level	1000	20A/1P	1	*			2	20A/1P	800	Lower Level	Emergency Lighting
Emergency Lighting	Stair 4	700	20A/1P	3		*		4	20A/1P	300	Exit Signs	Emergency Lighting
Emergency Lighting	Light	600	20A/1P	5			*	6	20A/1P	1000	Exit Signs	Emergency Lighting
Emergency Lighting	2nd Floor	600	20A/1P	7	*			8	20A/1P	0	0	Spare
Emergency Lighting	3rd Floor	890	20A/1P	9		*		10	20A/1P	0	0	Spare
Emergency Lighting	3rd Floor	550	20A/1P	11			*	12	20A/1P	0		Spare
Spare		0	20A/1P	13	*			14	20A/1P	0		Spare
Spare		0	20A/1P	15		*		16	20A/1P	0		Spare
Spare		0	20A/1P	17			*	18	20A/1P	0		Spare
Spare		0	20A/1P	19	*			20	20A/1P	0		Spare
Spare		0	20A/1P	21		*		22	20A/1P	0		Spare
Spare		0	20A/1P	23			*	24	20A/1P	0		Spare
		0	20A/1P	25	*			26	20A/1P	0		
		0	20A/1P	27		*		28	20A/1P	0		
		0	20A/1P	29			*	30	20A/1P	0		
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A	2.40	TOTAL DESIGN LOAD (KW)	9.66
CONNECTED LOAD (KW) - B	1.89	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	2.15	TOTAL DESIGN LOAD (AMPS)	27

Figure 48: Redesigned Panel APELGB

Panel APLGA

Panel APLGA is a lighting and appliance panel located in the second floor electrical closet. This panel is where the original design of the Library and the Grand Foyer lighting that was not going to be controlled by the theatrical was connected to. Because I will be reusing the same circuits and only adding two circuits to the panel, neither the overcurrent protection nor the 4#1AWG feeder will not need to be resized.

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W	PANEL TAG: ALPGA	MIN. C/B AIC: 10K
SIZE/TYPE BUS: 225A	PANEL LOCATION: Electrical Closet	OPTIONS:
SIZE/TYPE MAIN: 150A/3P C/B	PANEL MOUNTING: SURFACE	

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	Grand Foyer - 1	600	20A/1P	1	*			2	20A/1P	800		Receptacles
Lighting	Second Floor	1500	20A/1P	3		*		4	20A/1P	1200		Cleaning Outlets
Lighting	Second Floor	1700	20A/1P	5			*	6	20A/1P	800		Receptacles
Lighting	Library	800	20A/1P	7	*			8	20A/1P	400		Receptacles
Lighting	Library	800	20A/1P	9		*		10	20A/1P	800		Coat Rack
Cleaning Outlets		600	20A/1P	11			*	12	20A/1P	600		Receptacles
Fan		800	20A/1P	13	*			14	20A/1P	900	Grand Foyer - 2	Lighting
Fan		1080	20A/1P	15		*		16	20A/1P	1200		Receptacles
Fan		1080	20A/1P	17			*	18	20A/1P	800	Library	Lighting
Spare		0	20A/1P	19	*			20	20A/1P	0		Spare
Spare		0	20A/1P	21		*		22	20A/1P	0		Spare
Spare		0	20A/1P	23			*	24	20A/1P	0		Spare
Spare		0	20A/1P	25	*			26	20A/1P	0		Spare
Spare		0	20A/1P	27		*		28	20A/1P	0		Spare
Spare		0	20A/1P	29			*	30	20A/1P	0		Spare
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A	4.30	TOTAL DESIGN LOAD (KW)	21.88
CONNECTED LOAD (KW) - B	6.58	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	5.58	TOTAL DESIGN LOAD (AMPS)	61

Figure 49: Original Panel ALPGA

PANELBOARD SCHEDULE												
VOLTAGE: 208Y/120V,3PH,4W SIZE/TYPE BUS: 225A SIZE/TYPE MAIN: 150A/3P C/B			PANEL TAG: APLGA PANEL LOCATION: Electrical Closet PANEL MOUNTING: SURFACE						MIN. C/B AIC: 10K OPTIONS:			
DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	Grand Foyer - 1	1097	20A/1P	1	*			2	20A/1P	800		Receptacles
Lighting	Second Floor	1500	20A/1P	3		*		4	20A/1P	1200		Cleaning Outlets
Lighting	Second Floor	1700	20A/1P	5			*	6	20A/1P	800		Receptacles
Lighting	Library	1411	20A/1P	7	*			8	20A/1P	400		Receptacles
Lighting	Library	983	20A/1P	9		*		10	20A/1P	800		Coat Rack
Cleaning Outlets		600	20A/1P	11			*	12	20A/1P	600		Receptacles
Fan		800	20A/1P	13	*			14	20A/1P	1458	Grand Foyer - 2	Lighting
Fan		1080	20A/1P	15		*		16	20A/1P	1200		Receptacles
Fan		1080	20A/1P	17			*	18	20A/1P	1117	Grand Foyer - 2	Lighting
Lighting	Roof Terrace	889	20A/1P	19	*			20	20A/1P	1282	Roof Terrace	Lighting
Spare		0	20A/1P	21		*		22	20A/1P	0		Spare
Spare		0	20A/1P	23			*	24	20A/1P	0		Spare
Spare		0	20A/1P	25	*			26	20A/1P	0		Spare
Spare		0	20A/1P	27		*		28	20A/1P	0		Spare
Spare		0	20A/1P	29			*	30	20A/1P	0		Spare
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		
CONNECTED LOAD (KW) - A		8.14								TOTAL DESIGN LOAD (KW)		27.04
CONNECTED LOAD (KW) - B		6.76								POWER FACTOR		0.99
CONNECTED LOAD (KW) - C		5.90								TOTAL DESIGN LOAD (AMPS)		76

Figure 50: Redesigned Panel APLGA

Panel DP3A

Dimming panel DP3A originally carried the loads for the Grand Foyer lighting system, which was nearly entirely incandescent. Incandescent is used primarily for its ease of dimming as well as out of tradition. However, it is an extremely inefficient light source. The elimination of the incandescent in the Grand Foyer will allow for the panels to be reduced in size, therefore saving initial cost on top saving operational cost.

The original DP3A panel is a ETC DR12-48-120 panel which is a 48 circuit panel that interfaces with the rest of the theatrical control system. The universal dimmer modules of this system is capable of dimming the two-wire fluorescent ballasts specified in the Lighting Depth. After analysis, this panel is able to be resized to a ETC DR6-12-120 12 circuit dimming panel. Since the dimming equipment of this system can communicate with each other, the system can be expanded by adding panels anywhere in the system.

Therefore the relative low number of spare circuits on this panel is not concerning. With the reduction in loads, the feeder size can be reduced from 4#1/0AWG to 4#8AWG. This would change the size of the conduit from 2” down to ¾”. For redesign of the distribution panel that feeds DP3A, please see Distribution Panelboard Redesign.

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W	PANEL TAG: DP3A	MIN. C/B AIC: 22500
SIZE/TYPE BUS: 225A	PANEL LOCATION: Dimming Closet	OPTIONS:
SIZE/TYPE MAIN: MLO	PANEL MOUNTING: SURFACE	

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	Grand Foyer	1500	20A/1P	1	*			2	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1750	20A/1P	3		*		4	20A/1P	750	Grand Foyer	Lighting
Lighting	Grand Foyer	750	20A/1P	5			*	6	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	7	*			8	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	9		*		10	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	11			*	12	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	13	*			14	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	15		*		16	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	17			*	18	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	19	*			20	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	1000	20A/1P	21		*		22	20A/1P	1000	Grand Foyer	Lighting
Lighting	Grand Foyer	600	20A/1P	23			*	24	20A/1P	200	Grand Foyer	Lighting
Lighting	Institute	500	20A/1P	25	*			26	20A/1P	700	Institute	Lighting
Lighting	Institute	200	20A/1P	27		*		28	20A/1P	960	Institute	Lighting
Lighting	Exterior	660	20A/1P	29			*	30	20A/1P	1320	Exterior	Lighting
Lighting	Exterior	1200	20A/1P	31	*			32	20A/1P	180	Exterior	Lighting
Spare		0	20A/1P	33		*		34	20A/1P	0		Spare
Spare		0	20A/1P	35			*	36	20A/1P	0		Spare
Spare		0	20A/1P	37	*			38	20A/1P	0		Spare
Spare		0	20A/1P	39		*		40	20A/1P	0		Spare
Spare		0	20A/1P	41				42	20A/1P	0		Spare
Spare		0	20A/1P	43				44	20A/1P	0		Spare
Spare		0	20A/1P	45				46	20A/1P	0		Spare
Spare		0	20A/1P	47			*	48	20A/1P	0		Spare

CONNECTED LOAD (KW) - A	11.08	TOTAL DESIGN LOAD (KW)	43.91
CONNECTED LOAD (KW) - B	9.66	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	8.53	TOTAL DESIGN LOAD (AMPS)	122

Figure 51: Original Panel DP3A

PANELBOARD SCHEDULE

VOLTAGE: 208Y/120V,3PH,4W	PANEL TAG: DP3A	MIN. C/B AIC: 22500
SIZE/TYPE BUS: 225A	PANEL LOCATION: Dimming Closet	OPTIONS:
SIZE/TYPE MAIN: MLO	PANEL MOUNTING: SURFACE	

DESCRIPTION	LOCATION	LOAD (WATTS)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (WATTS)	LOCATION	DESCRIPTION
Lighting	Institute	500	20A/1P	1	*			2	20A/1P	700	Institute	Lighting
Lighting	Institute	200	20A/1P	3		*		4	20A/1P	960	Institute	Lighting
Curved Fluorescent	Grand Foyer	917	20A/1P	5			*	6	20A/1P	953	Grand Foyer	Curved Fluorescent
Curved Fluorescent	Grand Foyer	776	20A/1P	7	*			8	20A/1P	955	Entrance	South Entrance
North Entrance	Entrance	689	20A/1P	9		*		10	20A/1P	0		SPARE
SPARE		0	20A/1P	11			*	12	20A/1P	0		SPARE
		0	20A/1P	13	*			14	20A/1P	0		
		0	20A/1P	15		*		16	20A/1P	0		
		0	20A/1P	17			*	18	20A/1P	0		
		0	20A/1P	19	*			20	20A/1P	0		
		0	20A/1P	21		*		22	20A/1P	0		
		0	20A/1P	23			*	24	20A/1P	0		
		0	20A/1P	25	*			26	20A/1P	0		
		0	20A/1P	27		*		28	20A/1P	0		
		0	20A/1P	29			*	30	20A/1P	0		
		0	20A/1P	31	*			32	20A/1P	0		
		0	20A/1P	33		*		34	20A/1P	0		
		0	20A/1P	35			*	36	20A/1P	0		
		0	20A/1P	37	*			38	20A/1P	0		
		0	20A/1P	39		*		40	20A/1P	0		
		0	20A/1P	41			*	42	20A/1P	0		

CONNECTED LOAD (KW) - A	2.93	TOTAL DESIGN LOAD (KW)	9.98
CONNECTED LOAD (KW) - B	1.85	POWER FACTOR	0.99
CONNECTED LOAD (KW) - C	1.87	TOTAL DESIGN LOAD (AMPS)	28

Figure 52: Redesigned Panel DP3A

PHOTOVOLTAIC ARRAY FEASIBILITY STUDY

Due to ever increasing energy costs, increases in consumption, and demands on the infrastructure of the power grid, on-site energy production has become a worthwhile investment for many projects. Since this is a signature building for the city of Lancaster, setting a good example of responsibility in this area might be beneficial to the city and the local utilities. The geometry of the surrounding buildings in relation to this building and a current 30% federal tax credit make a photovoltaic array feasibility study seem more worthwhile.

To start off the feasibility study, I chose the GE Solar GEPVp-185-M photovoltaic module. I set aside 8480 ft^2 of roof area where mechanical equipment would not block the panels. Of this, about half would be used for the panels themselves assuming that the panels are sloped to an angle of 30 degrees. This area would support a 44.88 kW solar system.

Using the analysis program RETScreen, I analyzed the costs of a system and how much energy it would produce at the location of this building. The costs for the panels themselves will be $258,060 and the associated equipment to convert the DC power generated by the panels to AC usable to the building, the engineering, installation, and miscellaneous other equipment bring the total cost of this system to $547,432. This system would then be able to deliver about 59.8 MWh per year, taking into account conversion losses and inefficiencies. With an energy cost of $0.096 per kWh and an assumed 5% cost of energy escalation rate, it would take more than 25 years to achieve a positive cash flow with this system. Therefore a photovoltaic array is unfeasible at this time.

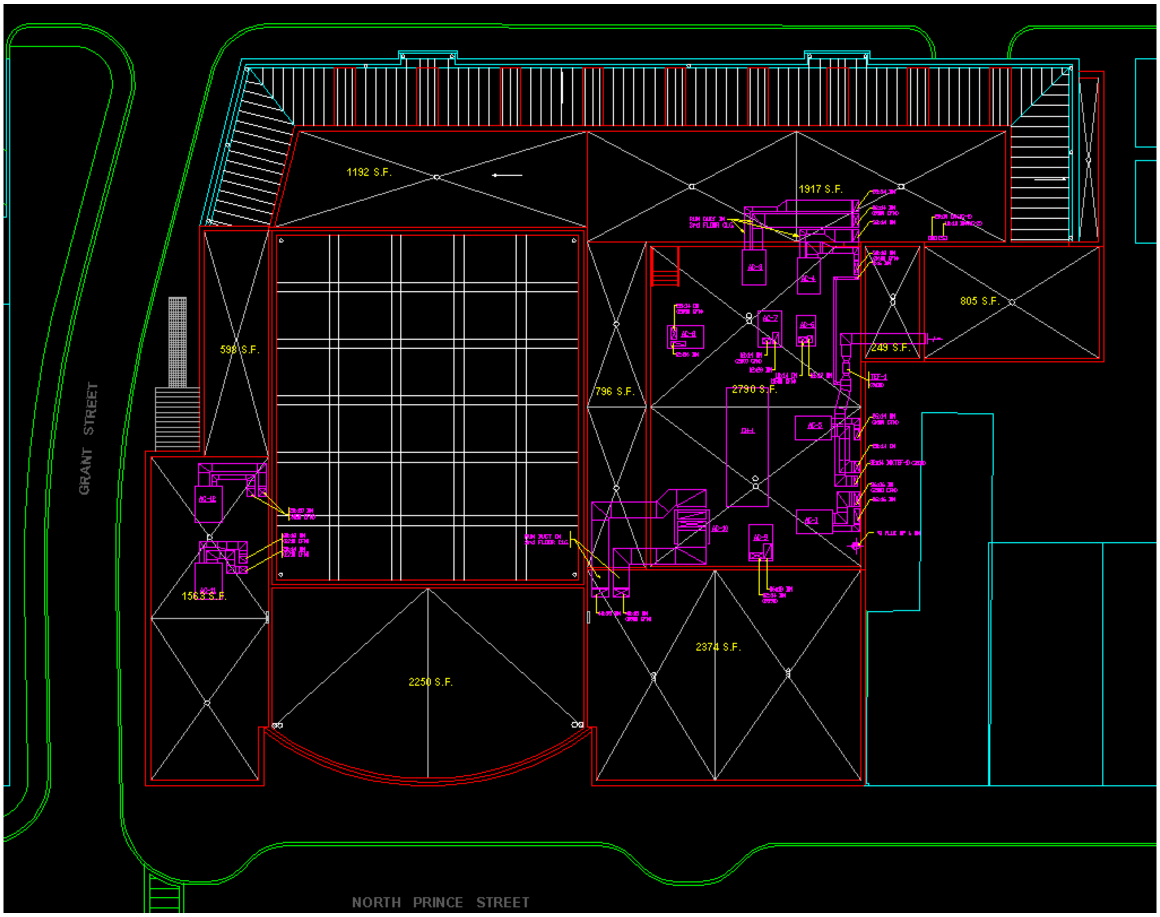

Figure 53: Building Roof Plan

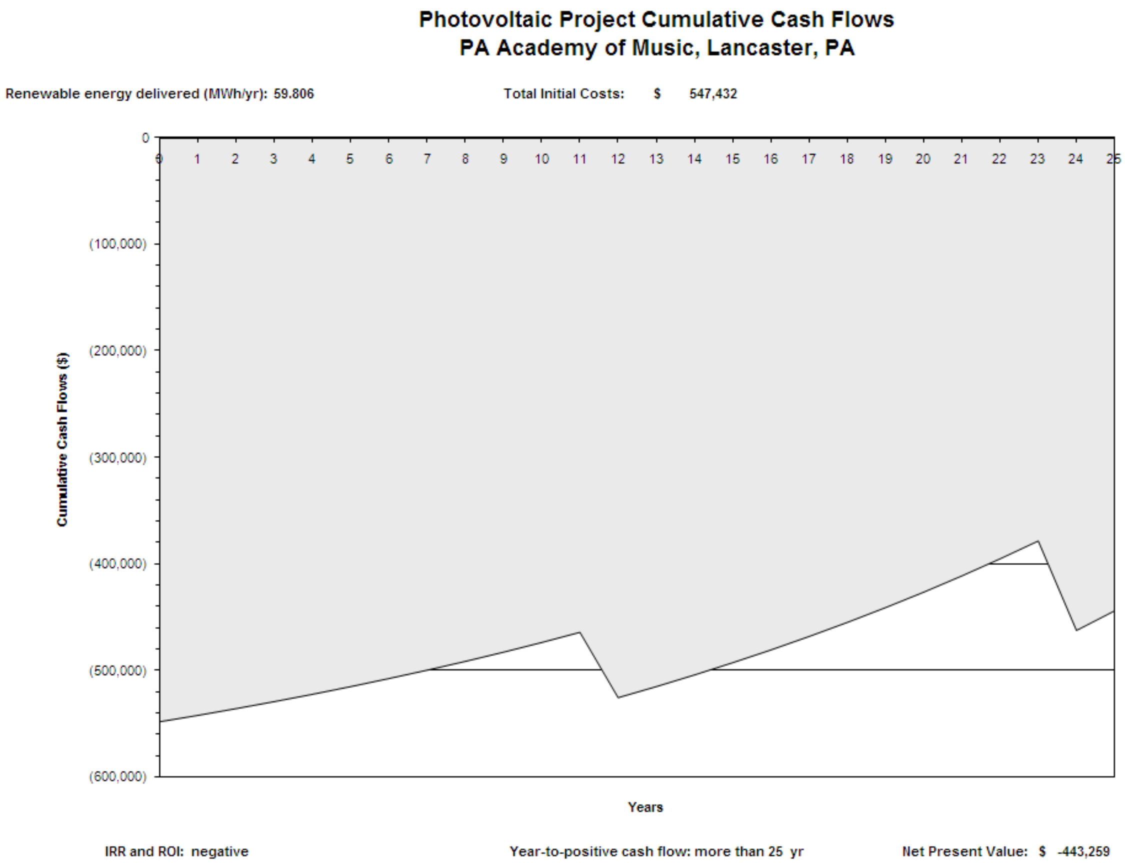

Figure 54: Photovoltaic Array Cash Flow Analysis

Yearly Cash Flows			
Year #	Pre-tax $	After-tax $	Cumulative $
0	(547,432)	(547,432)	(547,432)
1	6,019	6,019	(541,412)
2	6,293	6,293	(535,119)
3	6,582	6,582	(528,537)
4	6,885	6,885	(521,652)
5	7,205	7,205	(514,447)
6	7,540	7,540	(506,907)
7	7,893	7,893	(499,014)
8	8,265	8,265	(490,749)
9	8,656	8,656	(482,093)
10	9,067	9,067	(473,026)
11	9,499	9,499	(463,528)
12	(61,335)	(61,335)	(524,863)
13	10,431	10,431	(514,432)
14	10,934	10,934	(503,498)
15	11,462	11,462	(492,036)
16	12,018	12,018	(480,018)
17	12,602	12,602	(467,417)
18	13,216	13,216	(454,200)
19	13,862	13,862	(440,338)
20	14,541	14,541	(425,797)
21	15,255	15,255	(410,542)
22	16,006	16,006	(394,536)
23	16,795	16,795	(377,740)
24	(84,015)	(84,015)	(461,755)
25	18,497	18,497	(443,259)

Figure 55: Photovoltaic Array Cash Flow

RETScreen® Cost Analysis - Photovoltaic Project

Type of analysis: Feasibility | Currency: $ | Cost references: None

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
Feasibility Study							
Site investigation	p-h	8	$ 65	$ 520		-	-
Preliminary design	p-h	20	$ 65	$ 1,300		-	-
Report preparation	p-h	10	$ 65	$ 650		-	-
Travel and accommodation	p-trip	1	$ 1,200	$ 1,200		-	-
Other - Feasibility study	Cost	1	$ 10,000	$ 10,000		-	-
Credit - Base case system	Credit	1	$ 3,000	$ (3,000)		-	-
Sub-total :				**$ 10,670**	1.9%		
Development							
Permits and approvals	p-h	4	$ 65	$ 260		-	-
Project management	p-h	50	$ 85	$ 4,250		-	-
Travel and accommodation	p-trip	1	$ 2,000	$ 2,000		-	-
Other - Development	Cost	1	$ 15,000	$ 15,000		-	-
Credit - Base case system	Credit	1	$ 5,000	$ (5,000)		-	-
Sub-total :				**$ 16,510**	3.0%		
Engineering							
PV system design	p-h	15	$ 65	$ 975		-	-
Structural design	p-h	20	$ 65	$ 1,300		-	-
Electrical design	p-h	32	$ 65	$ 2,080		-	-
Tenders and contracting	p-h	11	$ 65	$ 715		-	-
Construction supervision	p-h	15	$ 65	$ 975		-	-
Other - Engineering	Cost	1	$ 55,000	$ 55,000		-	-
Credit - Base case system	Credit	1	$ 4,000	$ (4,000)		-	-
Sub-total :				**$ 57,045**	10.4%		
Energy Equipment							
PV module(s)	kWp	44.88	$ 5,750	$ 258,060		-	-
Transportation	project	0	$ -	$ -		-	-
Other - Energy equipment	Cost	0	$ -	$ -		-	-
Credit - Energy equipment	Credit	0	$ -	$ -		-	-
Sub-total :				**$ 258,060**	47.1%		
Balance of Equipment							
Module support structure	m^2	393.7	$ 100	$ 39,368		-	-
Inverter	kW AC	72.0	$ 1,000	$ 72,000		-	-
Other electrical equipment	kWp	44.88	$ -	$ -		-	-
System installation	kWp	44.88	$ 1,500	$ 67,320		-	-
Transportation	project	0	$ -	$ -		-	-
Other - Balance of equipment	Cost	0	$ -	$ -		-	-
Credit - Balance of equipment	Credit	0	$ -	$ -		-	-
Sub-total :				**$ 178,688**	32.6%		
Miscellaneous							
Training	p-h	6	$ 65	$ 390		-	-
Contingencies	%	5%	$ 521,363	$ 26,068		-	-
Sub-total :				**$ 26,458**	4.8%		
Initial Costs - Total				**$ 547,432**	100.0%		

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	Quantity Range	Unit Cost Range
O&M							
Property taxes/Insurance	project	0	$ -	$ -		-	-
O&M labour	p-h	16	$ 55	$ 880		-	-
Other - O&M	Cost	0	$ -	$ -		-	-
Credit - O&M	Credit	0	$ -	$ -		-	-
Contingencies	%	0%	$ 880	$ -		-	-
Sub-total :				**$ 880**	100.0%		
Annual Costs - Total				$ 880	100.0%		

Periodic Costs (Credits)		Period	Unit Cost	Amount		Interval Range	Unit Cost Range
Inverter Repair/Replacement	Cost	12 yr	$ 50,000	**$ 50,000**		-	-
			$ -	$ -		-	-
			$ -	$ -		-	-
End of project life		-	$ -	$ -			Go to GHG Analysis sheet

Figure 56: Photovoltaic Array Costs

DISTRIBUTION PANELBOARD REDESIGN

Due to the redesign of the DP3A dimming panel, I have decided to redesign the distribution panel that feeds it. This panel is DPLLB. It is fed by a 8x350 kcmil feeder in two 3” conduits from 150KVA transformer TR-3. It feeds the 300A DPRH panel with a 4#4/0AWG feeder, the 225A APL3A panel with a 4#1/0AWG feeder, and the redesigned 50A DP3A with a 4#8AWG feeder. Based on the revised size of panel DP3A, the feeder to this distribution panel can be downsized to a 8x250 kcmil feeder in one 3 ½” conduit.

Based on these sizes, I have selected a Cutler-Hammer PRL3a panel. Calculations for this panel are given in Table 38: Distribution Panel DPLLB Sizing. Based on this calculation, the catalog number of this panel will be the 53X size YS2890. The catalog products for these pages can be found in Appendix G: Electrical Equipment.

Panel	Amps	Feeder	Breaker Type	Size
Main Lugs	600	N/A	N/A	8X
DPRH	300	4/0	KD	15X
APL3A	225	1/0	JD	14X
DP3A	50	#8	EDH	7X
			TOTAL	**44X**

Table 38: Distribution Panel DPLLB Sizing

PROTECTIVE DEVICE COORDINATION STUDY

In this study, I have analyzed the circuit breakers at three points in the electrical system of The Pennsylvania Academy of Music. The first is a typical 20A branch circuit on panel APLGA. This is a G-series breaker. This panel is fed by distribution panel DPLLA, which is protected by a 400A, L-series breaker at the main switchgear on the other side of transformer TR-4. The main switchgear is protected from the utility with a 2500A main circuit breaker, which would be an L-series breaker. The coordination of these protective devices can be viewed in Figure 57: Protective Device Coordination Study.

For the transformer, the short circuit current is as follows:

$$R_{conductor} = \frac{L}{100} \text{ x } R \text{ x } \frac{1}{\text{sets}}$$

$$R_{conductor} = \frac{90\,\text{ft}}{100} \text{ x } 2.44\frac{\text{m}\Omega}{\text{ft}} \text{ x}1$$

$$R_{conductor} = 2.20\text{m}\Omega$$

$$X_{conductor} = \frac{L}{100} \text{ x } X \text{ x } \frac{1}{\text{sets}}$$

$$X_{conductor} = \frac{90\,\text{ft}}{100} \text{ x } 3.96\frac{\text{m}\Omega}{\text{ft}} \text{ x}1$$

$$X_{conductor} = 3.56\text{m}\Omega$$

$$I_{sc} = \frac{1000 \text{ x } V_{ln}}{Z_{conductor}}$$

$$I_{sc} = \frac{1000 \text{ x } 208}{\sqrt{2.20^2 + 3.56^2}}$$

$$I_{sc} = 49{,}702\text{A}$$

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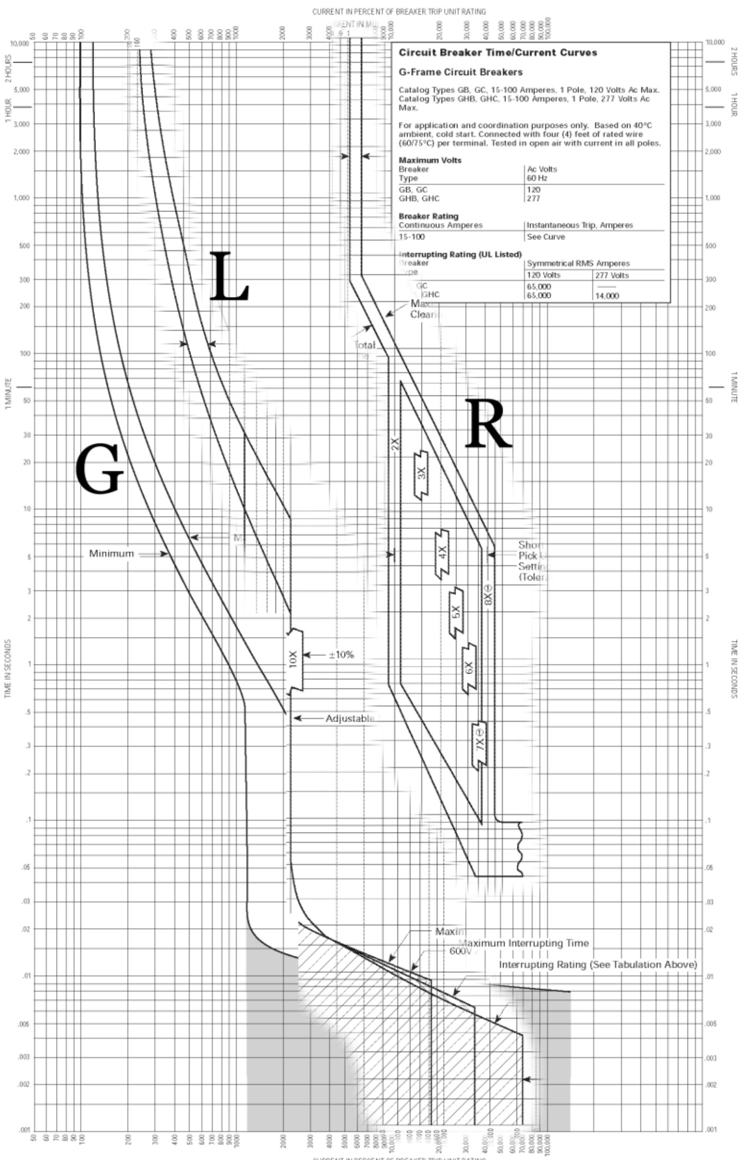
AB DE-ION Circuit Breakers

Types GB, GHB, GC, GHC 15-100 Amperes, 1 Pole



Curve No. SC-3500-83B

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Figure 57: Protective Device Coordination Study