1A. MAIN LOBBY and LIBERTY AVENUE FACADE [with SECOND LEVEL LOBBY, GIFT SHOP, BOX OFFICE, GRAND STAIRCASE]

Existing Design

The main lobby is a large space with few distinct boundaries that flows through most of the first floor of the building. It is a very important space in the building and control systems will be essential to a strong lighting and electrical system design.

The existing electrical design for the main lobby utilizes three separate lighting panels (1N1, 1E1, ALDR5). These panels are in various locations and control is split between dimming and switching. The other spaces that will be combined with the main lobby for the redesigned control system also use the three previously mentioned panels, as well as 2N1 and 2E1.

Redesigned System

The new electrical system for the lower and upper lobbies, as well as connected spaces, will combine many lighting loads onto a single dimming system. More dimming control was a goal for the redesigned lighting system and therefore it was a logical choice to combine these loads into a complete system, rather than using a collection of panels to supply power. A new dimming rack has been specified that is large enough to handle all the aforementioned loads. It also eliminates the need for separation of loads onto normal and emergency circuits due to an automatic emergency transfer switch located in the dimmer rack assembly. The panel specified for these spaces has eight modules with four control circuits per module with a maximum of 20A connected load per circuit. The panel is main lugs only and is protected at the distribution panel. Specifications are available in Appendix K.

The new system utilizes 27 circuits with a total of 27.07 KW of connected load and has six circuits of spare capacity. A total demand load of 93.99 A, including a 1.25 growth multiplier, was used to size the feeder and protection. The feeder has been sized at (4) #3 wires of type THW copper in 1.25" conduit. The breaker protecting the feeder on distribution panel 1NDP1 is sized at 100 A.

The 27 circuits are divided into 19 control zones. 16 of the 19 zones, those of the interior spaces, will be controlled by a single head unit located in the box office. The remaining zones will be controlled by a separate unit in the box office. These units will be linked together.

Dimmer rack/panelboard layouts for both the existing and new system are provided below. Electrical plans are available in Appendix F. Product Information for the dimmer racks and control units is available in Appendix H.

Redesign Analysis

The redesigned system offers incredible flexibility and greatly simplifies the existing system. Utilizing a main point of control will provide management with the ability to set and alter various scenes on the fly, creating a dynamic environment. Electrically, the system is convenient and centralized. The lighting loads are grouped together and are separated from the auditorium dimmer racks. The dimmer rack is located in a central location to help minimize cost and complexity of feeders.

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Area	Control Channel #	Circuit / Dimmer #	Description	Fixt. Type	Approx. # Fixt.	Watts / Fixture	Approx. Total Connected Load (Watts)	Load Type	E Circuit
Lobby	1	1	1st Floor Drum Lower	SAX	17	50	1063	ELV	
		2	1st Floor Drum Lower	SAX	17	50	1063	ELV	
	2	3	1st Floor Drum Upper		70	15	1313	NEON	
		4	1st Floor Drum Upper		70	15	1313	NEON	
	3	5	Art Lights Lobby	SBC	10	65	813	ELV	
	4	6	2nd Floor Drum	SAF	6	225	1350	INC	
		7	2nd Floor Drum	SAF	6	225	1350	INC	
		8	2nd Floor Drum	SAF	6	225	1350	INC	
		9	2nd Floor Drum	SAZ	6	225	1350	INC	
		10	Spare				0		
		11	Spare				0		
		12	Spare				0		

TOTAL:	10.96	k W

NOTE: Contractor must pull separate neutrals for each circuit.
A factor of 1.25 has been added to all LV, FL, & HID loads.

Figure 5.1A.1 | Dimmer Rack DR-201 – Existing Design – Layout Provided by Studio i Lighting. Yellow highlighting indicated loads involved in the redesign.

(SECOND FLOOR) PANEL 2N1

PANEL TYPE ______ MAIN LUGS ______ PANEL ☐ BUS RATING 208/120V 3Ø 4W

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
TELE 211, ELEC 212, 215 - LTG		.960		20	1	1		2	1	20		.605		OPEN OFFICE 220 LTG
LOBBY 201 & BRIDGE 200 - LTG.		.320				3		4				1.10		OPEN OFFICE 220 LTG
LOBBY 201 - LTG		.448				5		6				.320		HALLWAY 230 - LTG
LOBBY 201 - LTG		.512				7		8				.832		MENS 245, WOMENS 243 LTG
STAIR 204 - LTG		1.38				9		10				.924		CONF. RM. 240 - LTG
STAIR 204 - LTG		.500				11		12				.972		MULTI-PURPOSE 247 - LTG
SPARE						13		14				.840		MULTI-PURPOSE 247 - LTG
						15		16						SPARE
						17		18						
DIMMER ROOM LTG.		.128				19		20						
SPARE						21		22						
						23		24						
						25		26						
						27		28						
						29		30						
						31		32	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
						33		34	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
						35		36	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
AREA PROTECTION PANEL				20		37		38	1	60		3.2		TEMP. EXHIBIT 210 - BUS DUCT
						39		40	1	20				SPARE
					3	41		42	1	20				SPARE

4.3 KW 18.4 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE

K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______

FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______

VOLTAGE

TOTAL = 22.7 KW

Figure 5.1A.2 | Panel 2N1 – Existing Design – Layout Provided by Hornfeck Engineering.

(FIRST FLOOR) PANEL 1N1

PANEL TYPE ______ MAIN LUGS ______ PANEL ☐ BUS RATING 208/120V 3Ø 4W (LIGHTING PANEL)

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
HALLWAY 115 - LTG		1.20		20	1	1		2	1	20		.80		HALLWAY 131 - LTG
LOBBY 101 - LTG		.320				3		4				1.39		DRESSING RMS 126 - LTG
LOBBY 101 - LTG		1.12				5		6				1.60		DRESSING RMS 121 - LTG
LOBBY 101 - LTG		.448				7		8				.940		CHORUS DRESS RM 123 - LTG
GIFT SHOP 103 - LTG		1.20				9		10				.512		INNER LOBBY - LTG
GIFT SHOP 103 - LTG		.900				11		12				.832		MENS RM 145 WOMENS 143 - LTG
COAT CLOSET 107 - LTG		.480				13		14				.510		KITCHEN 140 - LTG
MEMBERSHIP BOX 102 - LTG		.810				15		16						SPARE
ENTRY 100 - LTG		.232				17		18						
SPARE						19		20						
SPARE						21		22						
EXTERIOR MAIN ENTRY		.052				23		24						
EXTERIOR LOAD DOCK LTG		.156				25		26	20					AREA PROTECTION
EXTERIOR TYPE SAY		.312				27		28						SPARE
EXTERIOR TYPE SAR		.35				29		30			3			SPARE
EXTERIOR TYPE SAR-A		.35				31		32	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
EXTERIOR TYPE SAG		.36				33		34	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
EXTERIOR TYPE SAG		.36				35		36	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
EXTERIOR TYPE SAB		.36				37		38	1	60		3.2		PERM. EXHIBIT 110 - BUS DUCT
SPARE						39		40						SPARE
SPARE						41		42						SPARE

9.0KW 19.4 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE

K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______

FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______

VOLTAGE

TOTAL = 28.4 KW

Figure 5.1A.3 | Panel 1N1 – Existing Design – Layout Provided by Hornfeck Engineering

LIFE SAFETY (SECOND FLOOR) PANEL 2E1

PANEL TYPE ___ MAIN LUGS ___ PANEL ☐ BUS RATING ___

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
PASSAGE WAY		.448		20	1	1		2	1	20		.36		FIRE SMOKE DAMPER
OPEN OFFICE HALLWAY		.672				3		4				.36		FIRE SMOKE DAMPER
REST ROOMS		.064				5		6				.36		SECURITY PANEL
SPARE						7		8				.36		AV RACK
						9		10				.36		AV RACK
						11		12						SPARE
STAIR NO. 1		.320				13		14				.36		FIRE ALARM NOTIFICATION (2)
SPARE						15		16						SPARE
						17		18						
						19		20						
						21		22						
						23		24						
						25		26						
						27		28						
						29		30						
						31		32						
						33		34						
						35		36						
						37		38						
						39		40						
						41		42						
		1.50 KW										2.16 KW		

TOTAL LOAD ___ PHASE A ___ POSITION SIZE
K.W. ___ AMPS ___ PHASE B ___ AT DIST. BOARD ___
FEEDER SIZE ___ PHASE C ___ FUSE OR TRIP ___
VOLTAGE TOTAL = 3.66 KW

Figure 5.1A.4 | Panel 2E1 – Existing Design – Layout Provided by Hornfeck Engineering

LIFE SAFETY (FIRST FLOOR) PANEL 1E1

PANEL TYPE ___ MAIN LUGS ___ PANEL ☐ BUS RATING ___

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
HALLWAY 113		.448		20	1	1		2	1	20		.360		FIRE SMOKE DAMPER
HALLWAY 131		.563				3		4				.360		FIRE SMOKE DAMPER
DRESSING RMS		.624				5		6				.360		SECURITY PANEL
LOBBY 100		.320				7		8				.360		AV RACK
LOBBY 101		.444				9		10				.360		AV RACK
STAIR NO. 6						11		12				.360		AV RACK
SPARE						13		14				.360		FIRE ALARM NOTIFICATION (1)
						15		16				.360		FIRE ALARM CONTROL PANEL
						17		18						SPARE
EXTERIOR LTG		.256				19		20						
SPARE						21		22						
						23		24						
						25		26						
						27		28						
						29		30						
						31		32						
						33		34						
						35		36						
						37		38						
						39		40						
						41		42						
		2.65 KW										2.88 KW		

TOTAL LOAD ___ PHASE A ___ POSITION SIZE
K.W. ___ AMPS ___ PHASE B ___ AT DIST. BOARD ___
FEEDER SIZE ___ PHASE C ___ FUSE OR TRIP ___
VOLTAGE TOTAL = 5.53 KW

Figure 5.1A.5 | 1E1 – Existing Design – Layout Provided by Hornfeck Engineering

D I M M E R   R A C K   L A Y O U T : DR101/201

AREA	CONTROL CHANNEL	CIRCUIT / DIMMER	DESCRIPTION	FIXT. TAG	NO. OF FIXT.	WATTS/ FIXTURE	MULT.	TOTAL WATTS	PHOTO CELL?	EMER. CRCT?
LOWER LOBBY	1	1	Theater Drum Upper	D	25	50	1.0	1250		
	2	2	Theater Drum Lower	D	25	50	1.0	1250		
	3	3	Downlights - Linear - 101	A	11	63	1.25	866	■	■
		4	Downlights - Linear - 101	A	17	63	1.25	1339		■
LOWER LOBBY	4	5	Downlights - Linear - 106	A	4	63	1.25	315		■
		6	Downlights - Linear 106 + P	A/F	8/4	63/32	1.25	790	■	
	5	7	Downlights - Round	E	15	49	1.25	919		
	6	8	Downlights - Cabinets	E1/H	7/4	50/49	1.25	683		
GIFT SHOP	7	9	Downlights	H	20	50	1.25	1250		
		10	Downlights	H	17	50	1.25	1063		■
Box Office	8	11	Downlights	E1/I	15/3	49/38	1.25	1061		
SPARE	9	12								
VESTIBULE	10	13	Downlights	I	6	38	1.25	285	■	■
STAIRCASE	11	14	Wallwash	C	4	300	1.0	1200		
		15	Wallwash	C	4	300	1.0	1200	`	
	12	16	Downlights	B	10	64	1.25	800		■
UPPER LOBBY	13	17	Theater Drum + Track	C	5	300	1.0	1800		
		18	Theater Drum + Track	C	5	300	1.0	1800		
		19	Theater Drum + Track	C	5	300	1.0	1800		
		20	Theater Drum + Track	C	4	300	1.0	1800		
UPPER LOBBY	14	21	Downlights - Linear	A	10	63	1.25	788	■	■
		21	Downlights - Linear	A	10	63	1.25	788		■
	15	22	Downlights - Round	E	13	49	1.25	796		■
	16	23	Downlights - Pendant	F	6	32	1.25	240		
EXTERIOR	17	25	Inside	R	85	10	1.25	1063		
		26	Inside	R	85	10	1.25	1063		
	18	27	Sail LED	S	120	3	1.25	450		
	19	28	Downlights - Exterior	M	15	22	1.25	413		
SPARE		29								
SPARE		30								
SPARE		31								
SPARE		32								

Panel Type: Lutron LP8/16-1204ML-20 — LOAD = 27.07 kW
Distribution Panel Power Supply: 1NDP1 — (125% GROWTH FACTOR) DEMAND LOAD = 93.99 A
Emergency Panel Power Supply: BE1 — FEEDER SIZE = (4) #3 in 1.25" Conduit
Location: Control Booth (151) — PROTECTION = 100 A

Figure 5.1A.6 | New Dimmer Rack DR101/201

1B. EDUCATION AND LECTURE ROOM and MEETING ROOM

Existing Design

The education and lecture room is a classroom space located on the Liberty Avenue side of the second level. The meeting room is adjacent to this space, located in the sail structure at the northeast corner of the building.

The current design for the education and lecture room and meeting room uses a dimmer rack (DR202) connected to a distribution panel (1N1). DR202 serves both spaces but no others. In total between the two rooms, 5 circuits were used. The total connected load was 5.13 KW, which was protected by a 100A three pole circuit breaker on panel 1NDP1. This system was controlled by a main control unit in room 202 with two satellite control units, one in each space. An emergency dimmer transfer rack, located in the same closet, was used to provide emergency power to the rack.

Redesigned System

The new system for the education and lecture room will utilize the same organization as the previous system. The lighting design is not extremely different and the load is nearly identical. There are new fixtures and different zones, but the total load is still very small. A new dimming rack has been specified that eliminates the need for a second emergency transfer panel. The panel specified for these spaces has four modules with four control circuits per module with a maximum of 20A connected load per circuit. The panel is main lugs only and is protected at the distribution panel. Specifications and additional information can be found in Appendix H.

The new system utilizes 8 circuits with a total of 6.48 KW of connected load and has eight circuits of spare capacity. A total demand load of 27A, including a 1.5 growth multiplier, was used to size the feeder and protection. The feeder has been sized at (4) #10 THW 75 C copper conductors in ½" conduit. The breaker protected the feeder on distribution panel 1NDP1 is still sized at 30A.

The system will be controlled by two main wall panels, one in the meeting room and one in the education room. The education room will also feature a secondary control panel. These panels will control both the lights and the window shades that are present in both rooms. Photosensors will be added to the education room to dim the exterior zones because daylight analysis shows that ample daylight is available in the space.

Dimmer rack layouts for both the existing and new system are provided below. See Electrical plans are available in Appendix F.

Redesign Analysis

The new system does not differ dramatically from the existing system, but the system is simplified slightly by eliminating an external emergency power transfer rack. The streamlined control system will allow for control of both lighting and shading devices. Extra room is left should the need to expand the system arise.

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Area	Control Channel #	Circuit / Dimmer #	Description	Fixt. Type	Approx. # Fixt.	Watts / Fixture	Approx. Total Connected Load (Watts)	Load Type	E Circuit
Educ. Class	1	1	Linear Fluorescent	SK	3	324	1215	FL	
		2	Linear Fluorescent	SK	4	324	1620	FL	
	2	3	Low Voltage Downlight	SK-a	21	50	1313	MLV	·
Conf. Room	3	4	Linear Fluorescent	SD1	8	54	540	FL	
	4	5	Linear Fluorescent	SD1	8	54	540	FL	·
		6	Spare				0		
		7	Spare				0		
		8	Spare				0		
		9	Empty				0		
		10	Empty				0		
		11	Empty				0		
		12	Empty				0		
						TOTAL:	5.23	kW	

NOTE: Contractor must pull separate neutrals for each circuit.
A factor of 1.25 has been added to all LV, FL, & HID loads.

Figure 5.1B.1 | Dimmer Rack DR-202/207 – Existing Design – Layout Provided by Studio i Lighting

DIMMER RACK LAYOUT: DR202/207										
AREA	CONTROL CHANNEL	CIRCUIT / DIMMER	DESCRIPTION	FIXT. TAG	NO. OF FIXT.	WATTS/ FIXTURE	MULT.	TOTAL WATTS	PHOTO CELL?	EMER. CRCT?
EDUCATION	1	1	Northwest Downlights + Track	A	5	125	1.25	1141.25	■	
	2	2	Northeast Downlights + Track	A	5	125	1.25	1141.25	■	
	3	3	Southwest Downlights + Track	A	5	125	1.25	1141.25		■
	4	4	Southeast Downlights + Track	A	5	125	1.25	1141.25		■
MEETING	5	5	Pendants	L	3	116	1.25	435		
	6	6	Downlights	E1	8	49	1.25	490		■
	7	7	Accent - Wood/Sail	J	13	50	1.25	812.5		
	8	8	Linear Wallwasher	K	4	35	1.25	175		
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
SPARE										
Panel Type: Lutron LP4/16-1204ML-20							LOAD =	6.48	kW	
Distribution Panel: 1NDP1							(200% GROWTH FACTOR) DEMAND LOAD =	26.99	A	
Emergency Panel: BE1							FEEDER SIZE =	(3) #10	in .5" Conduit	
Location: 202 Closet							PROTECTION =	30	A	

Figure 5.1B.2 | New Dimmer Rack DR-202/207

2. PHOTOVOLTAIC ARRAY ANALYSIS

With the growth of the LEED movement, photovoltaic (PV) systems are surging as a popular 'green' choice for owners who want an energy conscious design. With numerous government incentives available, the cost-effectiveness of implementing such a system can become complex. As a building seeking LEED certification, a PV system is something that should at least be considered by the designer.

This analysis was conducted utilizing RETScreen, an analysis tool for energy design. Since enough area is not available to provide power for the entire building, the system needs to be an on-grid system. The designed system would not use a battery supply and excess energy would be transferred back to the grid. The following is a summary of the analysis:

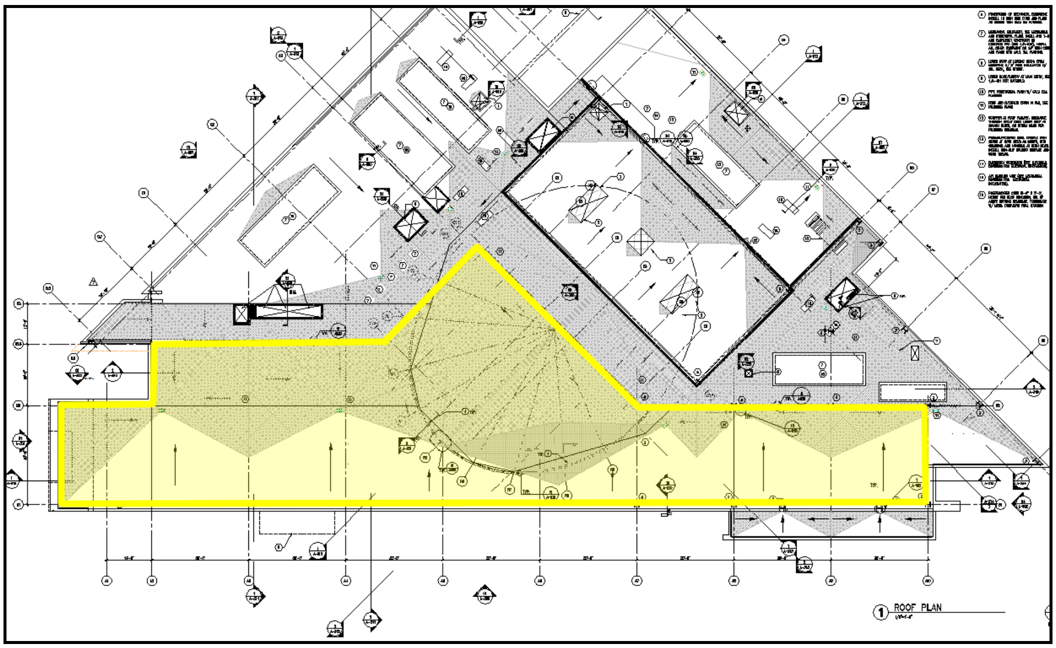

Figure 5.2.1 | Available Area for PV Array

Roof Area available for PV array: Approximately 12,000 ft^2 (1115 m^2)

Product: BP Solar 5170S

Power Produced: 192KWh

Physical Size: 1.26 m^2

Efficiency: 13.5%

Total System Efficiency (Combined Panel and System): 3%

Unit Cost: $5,750

Maintenance Costs: $10,000/10 Years

Design Costs: $15,000

Other Equipment Costs (inverter and power equipment): $100,000

Annual Energy Available (Pittsburgh): 1.53MWh/m^2

Energy Rate: .1236 cents/KWh

Energy Savings/Year/Panel: $28

Financial Incentives:

- *Federal tax incentives* do not apply since the August Wilson Center is a non-profit organization.
- The *Pennsylvania Energy Harvest Grant,* or any other state incentive, is no longer available.
- *Duquesne Light* does not currently offer any incentives for implementation of renewable energy.

Payback Period: This installation will never provide a return on the investment.

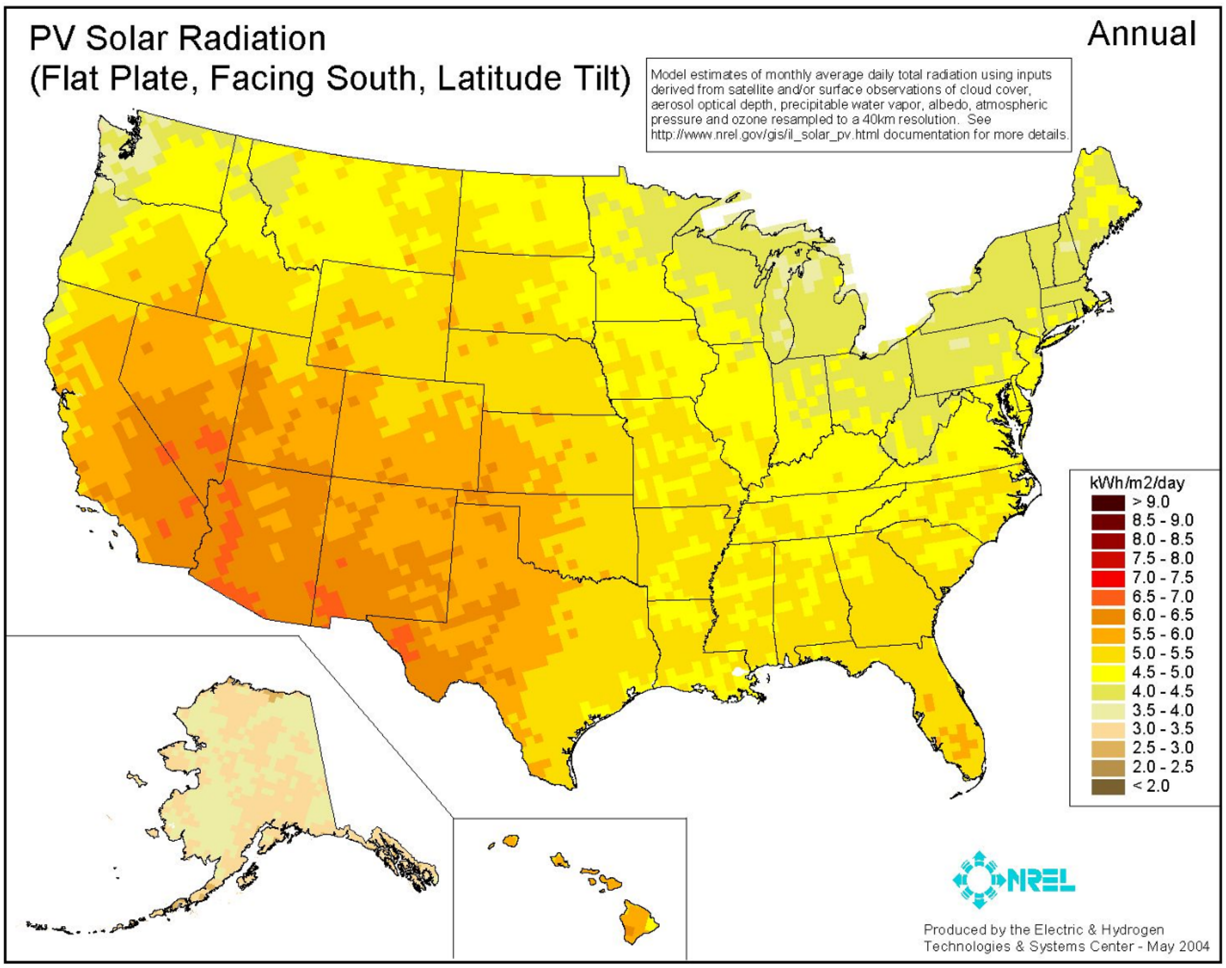

Figure 5.2.2 | PV Solar Radiation Map (From Electric & Hydrogen Technologies & Systems Center – May 2004)

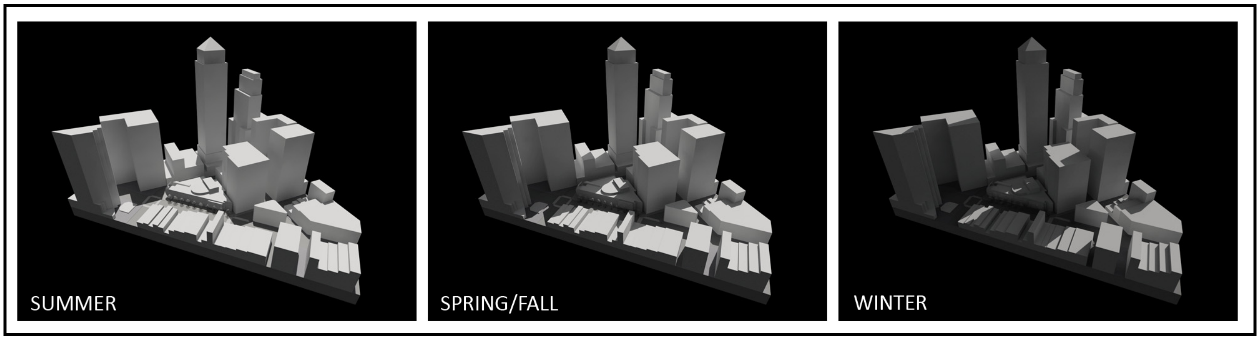

Figure 5.2.3 | Site shadow conditions midday throughout the year. The August Wilson Center is at the center of the model.

Photovoltaic Array Feasibility Conclusion:
Based on the calculations, it is certainly not feasible to use a photovoltaic array for this project. Figure 5.2.2 shows that Pittsburgh does not receive a substantial amount of solar energy. Additionally based on the buildings location in the urban center of Pittsburgh and the shadowing by adjacent buildings (Figure 5.2.3), the actual energy savings would likely be less that the model predicts. The PV array would likely receive direct sunlight at noon on less than half of the days during the year.

Another factor affecting the feasibility is the low utility rate that this property receives. Finally, since the August Wilson Center is a non-profit organization, it cannot receive federal and state tax incentives for solar energy. This places the full cost of the initial installation on the owner, significantly affecting the payback of the system. Even without considered specific system characteristics, it is evident that PV energy production is not a cost effective choice for the August Wilson Center. In order for the system to have reasonable payback period, the panels would have to be far more efficient than what is currently available.

3. SYSTEM TYPE CONVERSION STUDY

The existing design for the August Wilson Center utilizes two parallel service entrances, providing redundancy should one fail through a collector bus which connects to two main switchboards. One of the switchboards (MSB1) feeds primarily mechanical loads and the emergency power system while the second switchboard (MSB2) feeds predominantly lighting and receptacle loads. Both switchboards are currently designed at 280Y/120V.

Studying the single line diagram revealed that MSB1 could be changed to a 480/277V system with minimal disruption to the system. One drawback to this change is the elimination of the point of redundancy, however. In order to make a justifiable decision on the advantage of the system conversion, a comparative cost analysis was conducted.

The Existing System:

The portion of the existing system being studied includes the following equipment. The Duquesne Light Transformer has not been included in the cost comparison because it is the responsibility of the utility company.

Table 5.3.1: Existing Design Equipment Schedule

TYPE	TAG	LOCATION	DESCRIPTION
Transformer	*NA*	Transformer Vault	Duquesne Light Transformer
Main Switchboard	MSB1	Basement (013)	208Y/120, 3000A MCB
Distribution Panel	BNDP1	Basement (013)	208Y/120, 1200A MLO
Distribution Panel	BNDP2	Basement (013)	208Y/120, 400A MLO
Branch Circuit Panel	2P1	Electrical Room (212)	208Y/120, 225A MLO
Branch Circuit Panel	1KN1	Kitchen (140)	208Y/120, 400A MLO
Branch Circuit Panel	1KN2	Kitchen (140)	208Y/120, 225A MLO

A portion of the existing single line diagram as well as the panelboards that will change are shown on the following pages.

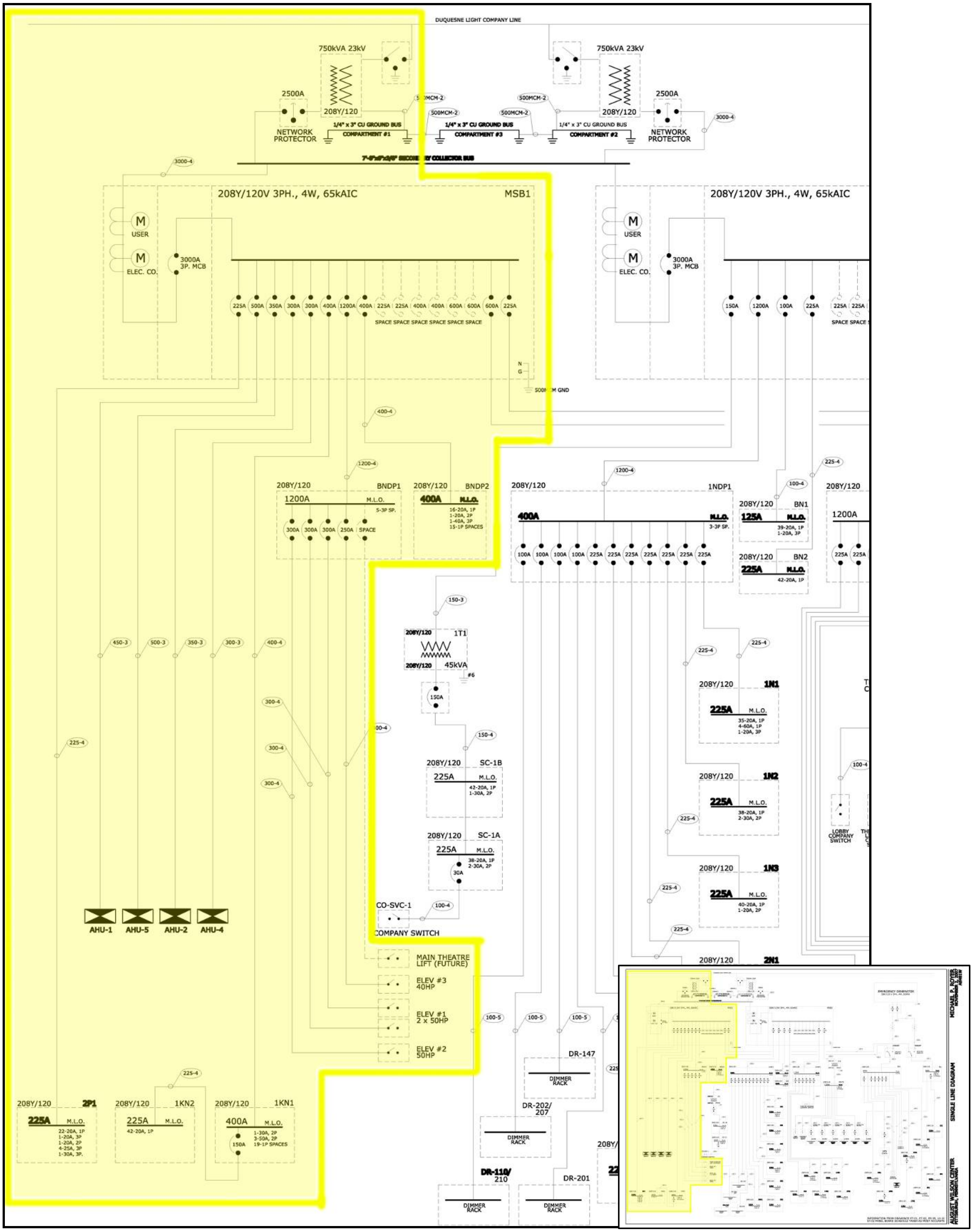

Figure 5.3.1 | Single Line Diagram for existing system. Highlight shows area to be redesigned. Existing and new Single Line Diagrams are available at a larger scale in Appendix G.

BASEMENT (ELEVATORS) DISTR. PANEL BNDP 1

PANEL TYPE | MAIN LUGS 1200 A | PANEL | BUS RATING

DESCRIPTION	Wire Size	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	Wire Size	DESCRIPTION
ELEVATOR NO. 1		54.0		300		1		2		300		54.0		ELEVATOR NO. 1
50.0HP						3		4						50.0HP
(150.0 FLA)					3	5		6			3			(150.0 FLA)
ELEVATOR NO. 2		54.0		300		7		8		250		43.2		ELEVATOR NO. 3
50.0HP						9		10						40.0HP
(150.0 FLA)					3	11		12			3			(120.0 FLA)
SPACE						13		14				0.0		SPACE
					1	15		16						MAIN THEATRE
					3	17		18			3			LIFT (FUTURE)
SPACE						19		20						SPACE
					1	21		22						
					3	23		24			3			
SPACE						25		26						SPACE
						27		28						
					3	29		30			3			
						31		32						
						33		34						
						35		36						
						37		38						
						39		40						
						41		42						
		108.0 KW										97.2 KW		

TOTAL LOAD | K.W. AMPS | FEEDER SIZE | VOLTAGE | PHASE A | PHASE B | PHASE C | POSITION SIZE | AT DIST. BOARD | FUSE OR TRIP

TOTAL = 205.2 KW

Figure 5.3.2 | BNDP1 – Existing Design – Layout Provided by Hornfeck Engineering

BASEMENT (MECHANICAL) DISTR. PANEL BNDP2

PANEL TYPE | MAIN LUGS 400A | PANEL | BUS RATING

DESCRIPTION	Wire Size	K.W.	AMPS	TRIP	POLE	CIRC.	PHASE A B C	CIRC	POLE	TRIP	AMPS	K.W.	Wire Size	DESCRIPTION
DOMESTIC WATER HTR CONTROL PANEL		.36		20	1	1		2	20			1.9		AC-1 AC-2
DHWP-1 & DHWP-2 (1/12HP) (1/12HP)		.60				3		4		2				(6.3 FLA) (2.8 FLA)
DOMESTIC HOT WTR HTR DWH-1		.60				5		6		20				SPARE
SPARE						7		8						
						9		10						
						11		12						
					1	13		14						
					1	15		16						
						17		18						
SPACE		17				19		20		40		6.3		LOADING DOCK
					1	21		22						LIFT MOTOR
					3	23		24			3			5.0 HP 17.5 FLA
						25		26						SPACE
						27		28						
						29		30						
						31		32						
						33		34						
						35		36						
						37		38						
						39		40						
						41		42						
		1.6 KW										8.2 KW		

TOTAL LOAD | K.W. AMPS | FEEDER SIZE | VOLTAGE | PHASE A | PHASE B | PHASE C | POSITION SIZE | AT DIST. BOARD | FUSE OR TRIP

TOTAL = 9.8 KW

Figure 5.3.3 | BNDP2 – Existing Design – Layout Provided by Hornfeck Engineering

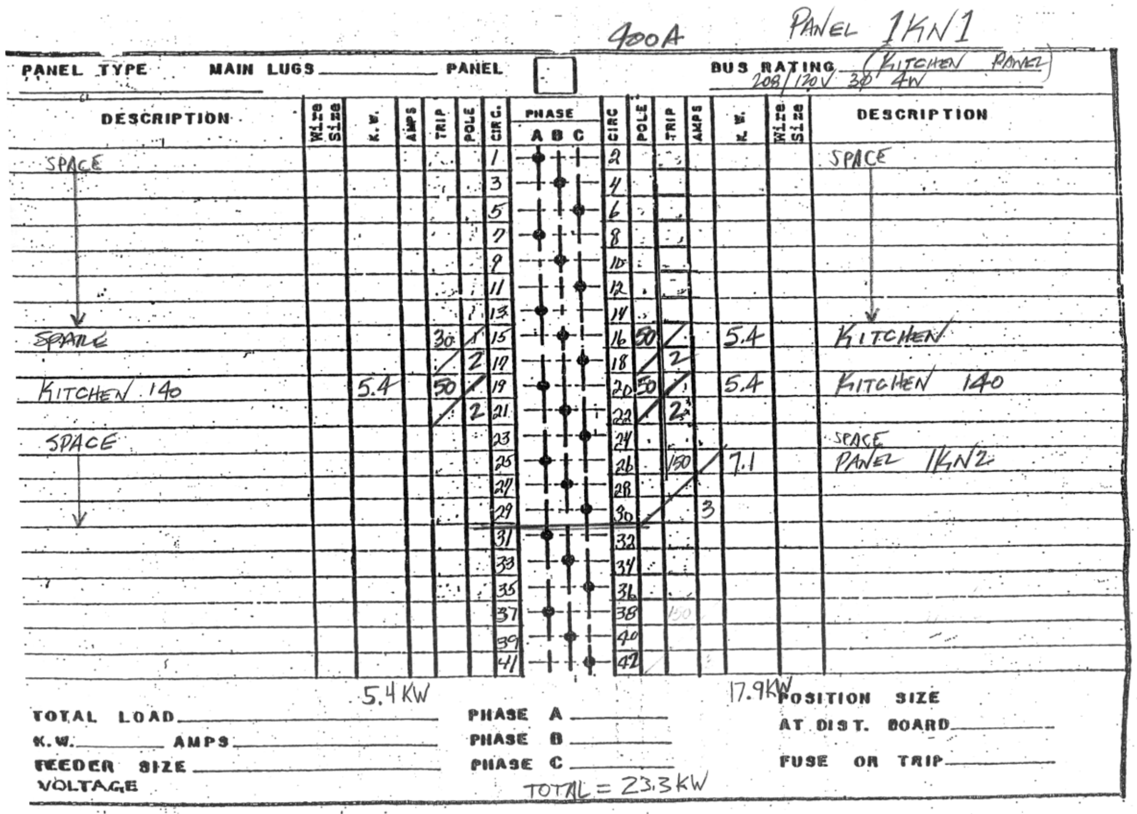

Figure 5.3.4 | 1KN1 – Existing Design – Layout Provided by Hornfeck Engineering

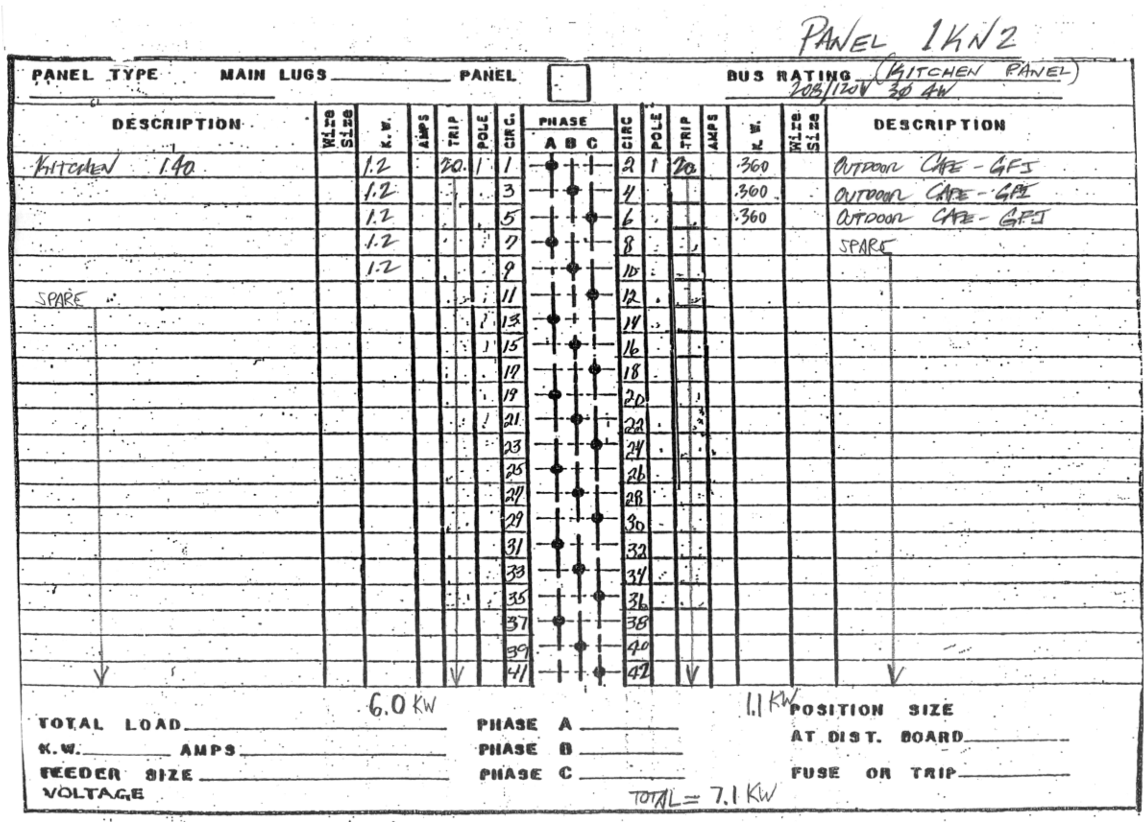

Figure 5.3.5 | 1KN2 – Existing Design – Layout Provided by Hornfeck Engineering

PANEL 2P1

PANEL TYPE MAIN LUGS ______ PANEL ☐ BUS RATING 208/120V 3Ø 4W MECH

DESCRIPTION	WIRE SIZE	K.W.	AMPS	TRIP	POLE	CIRC.	CIRC	POLE	TRIP	AMPS	K.W.	WIRE SIZE	DESCRIPTION
WP ROOF TOP GFI RECEPT		.720		20	1	1	2	1	20		.54		WP ROOF TOP GFI RECEPT
↓		.720				3	4				.54		↓
HEAT TRACE						5	6				.72		
SPARE						7	8						SPARE
AHU-1 LTG & CONTROLS		.72				9	10				.72		AHU-4 LTG & CONTROLS
AHU-2 LTG & CONTROLS		.72				11	12				.72		AHU-5 LTG & CONTROLS
SPARE					1	13	14						SPARE
SPARE					1	15	16						SPARE
EXH. FAN EF-3 1/3HP		.864				17	18				.864		EXHAUST FAN EF-1 1/3HP
SPARE						19	20						SPARE
					1	21	22		20		2.662		COND. UNIT CU-4 (208V 1Ø)
↓						23	24			2			12.8 FLA
COND. UNIT CU-1 (208V 3Ø)		4.60		25		25	26		25		4.60		COND. UNIT CU-5 (208V 3Ø)
12.8 FLA						27	28						12.8 FLA
					3	29	30			3			
COND. UNIT CU-2 (208V 3Ø)		4.60		25		31	32		20		1.49		EXHUAST FAN EF-2 1.0HP
12.8 FLA						33	34						4.14 FLA
					3	35	36			3			
COND. UNIT CU-3 (208V 3Ø)		4.60		25		37	38		30				SPARE
12.8 FLA						39	40						
					3	41	42			3			

17.5 KW 12.9 KW

TOTAL LOAD ______ PHASE A ______ POSITION SIZE

K.W. ______ AMPS ______ PHASE B ______ AT DIST. BOARD ______

FEEDER SIZE ______ PHASE C ______ FUSE OR TRIP ______

VOLTAGE TOTAL = 30.4 KW

Figure 5.3.6 | 2P1 – Existing Design – Layout Provided by Hornfeck Engineering

The Redesigned System:

Redesigning the system involved recalculating the loading on each panelboard in order to resize the bus and the feeder. Also, the addition of two transformers is necessary to accommodate loads that must run at 120V. Below is the new equipment schedule and panelboard schedules. A new single line diagram is available in Appendix G

Table 5.3.2: Redesign Equipment Schedule			
TYPE	TAG	LOCATION	DESCRIPTION
Transformer	*NA*	*Trans. Vault*	*Duquesne Light Transformer*
Transformer	2T1	Electrical Room (212)	9 KVA, 480V to 108Y/120V
Transformer	1T3	Kitchen (140)	30 KVA, 480V to 108Y/120V
Main Switchboard	MSB1	Basement (013)	480/277, 1600A MCB
Distribution Panel	BNDP1	Basement (013)	480/277, 400A MLO
Distribution Panel	BNDP2	Basement (013)	480/277, 100A MLO
Branch Circuit Panel	2P1	Electrical Room (212)	480/277, 100A MLO
Branch Circuit Panel	2P1A	Electrical Room (212)	480/277, 60A MLO
Branch Circuit Panel	1KN1	Kitchen (140)	208Y/120, 400A MCB
Branch Circuit Panel	*1KN2*	*Kitchen (140)*	*208Y/120, 225A MLO (Unchanged)*

Table 5.3.3: Feeder Sizes For Converted System							
TAG	FROM	TO	SETS	NO. WIRES	TYPE	SIZE	CONDUIT
A	TRANS.	MSB1	4	4	CU THWN	500	3" EMT
B	MSB1	2P1	1	4	CU THWN	#6	1" EMT
C	MSB1	AHU-1	1	4	CU THWN	2/0	2" EMT
D	MSB1	AHU-5	1	4	CU THWN	3/0	2" EMT
E	MSB1	AHU-2	1	4	CU THWN	#1	1.5" EMT
F	MSB1	AHU-4	1	4	CU THWN	#2	1.25" EMT
G	MSB1	1T3	1	4	CU THWN	#3	1.25" EMT
H	MSB1	BNDP1	1	4	CU THWN	400	3" EMT
I	MSB1	BNDP2	1	4	CU THWN	#8	1" EMT
J	BNDP1	ELEV 2	1	4	CU THWN	#4	1.25" EMT
K	BNDP1	ELEV 1	1	4	CU THWN	#4	1.25" EMT
L	BNDP1	ELEV 1	1	4	CU THWN	#4	1.25" EMT
M	BNDP1	ELEV 3	1	4	CU THWN	#6	1" EMT
N	2P1	2T1	1	4	CU THWN	#10	1/2" EMT
O	2T1	2P1A	1	4	CU THWN	#10	1/2" EMT
P	1KN1	1KN2	1	4	CU THWN	#6	1" EMT
Q	1T3	1KN1	1	4	CU THWN	#2	1.25" EMT

PANEL BOARD SCHEDULE

VOLTAGE: 480/277V,3PH,4W SIZE/TYPE BUS: 400A SIZE/TYPE MAIN: M.L.O	PANEL TAG: BNDP1 PANEL LOCATION: BASEMENT B013 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 25K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
ELEVATOR NO. 1 (50 HP)	18000	150A/3P	1	*			2	150A/3P	18000	ELEVATOR NO. 1 (50 HP)
[65 FLA]	18000		3		*		4		18000	[65 FLA]
	18000		5			*	6		18000	
ELEVATOR NO. 2 (50 HP)	18000	150A/3P	7	*			8	100A/3P	14400	ELEVATOR NO. 3 (40HP)
[65 FLA]	18000		9		*		10		14400	[52 FLA]
	18000		11			*	12		14400	
SPARE		150A/3P	13	*			14	150A/3P		*FUTURE LIFT*
			15		*		16			
			17			*	18			
SPARE		150A/3P	19	*			20	150A/3P		SPARE
			21		*		22			
			23			*	24			
SPARE		100A/3P	25	*			26	100A/3P		SPARE
			27		*		28			
			29			*	30			

CONNECTED LOAD (KW) - A	68.40	TOTAL DESIGN LOAD (KW)	205.20
CONNECTED LOAD (KW) - B	68.40	SPACE (GROWTH) FACTOR	1.35
CONNECTED LOAD (KW) - C	68.40	TOTAL DESIGN LOAD (A)	333

Figure 5.3.7 | New Panel BNDP1

PANEL BOARD SCHEDULE

VOLTAGE: 480/277V,3PH,4W SIZE/TYPE BUS: 100A SIZE/TYPE MAIN: M.L.O.	PANEL TAG: BNDP2 PANEL LOCATION: BASEMENT B013 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 25K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
DOMESTIC WATER HTR CONTL	360	20A/1P	1	*			2	20A/2P	950	AC-1 & AC-2
DHWP-1 & DHWP-2 (1/12 HP EA)	600	20A/1P	3		*		4		950	[2.73 + 1.21 FLA]
DOMESTIC HOT WATER HTR DHW-1	600	20A/1P	5			*	6	20A/1P		SPARE
SPARE		20A/1P	7	*			8	20A/1P		SPARE
SPARE		20A/1P	9		*		10	20A/1P		SPARE
SPARE		20A/1P	11			*	12	20A/1P		SPARE
SPARE		20A/1P	13	*			14	20A/1P		SPARE
SPARE		20A/1P	15		*		16	20A/1P		SPARE
SPARE		20A/1P	17			*	18	20A/1P		SPARE
SPACE			19	*			20	20A/3P	2100	LOADING DOCK LIFT MOTOR (5 HP)
SPACE			21		*		22		2100	[7.58 FLA]
SPACE			23			*	24		2100	
SPACE			25	*			26			SPACE
SPACE			27		*		28			SPACE
SPACE			29			*	30			SPACE
SPACE			31	*			32			SPACE
SPACE			33		*		34			SPACE
SPACE			35			*	36			SPACE

CONNECTED LOAD (KW) - A	3.41		TOTAL DESIGN LOAD (KW)	9.76
CONNECTED LOAD (KW) - B	3.65		SPACE (GROWTH) FACTOR	1.50
CONNECTED LOAD (KW) - C	2.70		TOTAL DESIGN LOAD (A)	20

Figure 5.3.8 | New Panel BNDP2

PANEL BOARD SCHEDULE

VOLTAGE: 480/277V,3PH,4W SIZE/TYPE BUS: 100A SIZE/TYPE MAIN: M.L.O.	PANEL TAG: 2P1 PANEL LOCATION: ELECTRICAL ROOM 212 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 22K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
EXH FAN EF-3 (1/3 HP)	864	20A/1P	1	*			2	20A/1P	864	EXH FAN EF-1 (1/3 HP)
SPARE		20A/1P	3		*		4	20A/1P		SPARE
SPARE		20A/1P	5			*	6	20A/2P	1331	COND UNIT CU-4
SPARE		20A/1P	7	*			8		1331	[5.54 FLA]
COND UNIT CU-1	1533	20A/3P	9		*		10	20A/3P	1533	COND UNIT CU-5
[5.54 FLA]	1533		11			*	12		1533	[5.54 FLA]
	1533		13	*			14		1533	
COND UNIT CU-2	1533	20A/3P	15		*		16	20A/3P	497	EXH FAN EF-2 (1.0 HP)
[5.54 FLA]	1533		17			*	18		497	[1.79 FLA]
	1533		19	*			20		497	
COND UNIT CU-3	1533	20A/3P	21		*		22	20A/3P	2500	PANEL 2P1A
[5.54 FLA]	1533		23			*	24		2500	
	1533		25	*			26		2500	
SPACE			27		*		28			SPACE
SPACE			29			*	30			SPACE
SPACE			31	*			32			SPACE

CONNECTED LOAD (KW) - A	12.19		TOTAL DESIGN LOAD (KW)	31.78
CONNECTED LOAD (KW) - B	9.13		SPACE (GROWTH) FACTOR	1.25
CONNECTED LOAD (KW) - C	10.46		TOTAL DESIGN LOAD (A)	51

Figure 5.3.9 | New Panel 2P1

PANEL BOARD SCHEDULE		
VOLTAGE: 208Y/120V,3PH,4W SIZE/TYPE BUS: 60A SIZE/TYPE MAIN: M.L.O.	PANEL TAG: 2P1A PANEL LOCATION: ELECTRICAL ROOM 212 PANEL MOUNTING: SURFACE	MIN. C/B AIC: 22K OPTIONS:

DESCRIPTION	LOAD (W)	C/B SIZE	POS. NO.	A	B	C	POS. NO.	C/B SIZE	LOAD (W)	DESCRIPTION
WP ROOF TOP GFI RCPT	720	20A/1P	1	*			2	20A/1P	540	WP ROOF TOP GFI RCPT
WP ROOF TOP GFI RCPT	720	20A/1P	3		*		4	20A/1P	540	WP ROOF TOP GFI RCPT
HEAT TRACE	0	20A/1P	5			*	6	20A/1P	720	WP ROOF TOP GFI RCPT
SPARE	0	20A/1P	7	*			8	20A/1P	0	SPARE
AHU-1 LTG & CONTROLS	720	20A/1P	9		*		10	20A/1P	720	AHU-4 LTG & CONTROLS
AHU-2 LTG & CONTROLS	720	20A/1P	11			*	12	20A/1P	720	AHU-5 LTG & CONTROLS
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
SPACE			19	*			20			SPACE
SPACE			21		*		22			SPACE
SPACE			23			*	24			SPACE

CONNECTED LOAD (KW) - A	1.26	TOTAL DESIGN LOAD (KW)	7.50
CONNECTED LOAD (KW) - B	2.70	POWER FACTOR	1.00
CONNECTED LOAD (KW) - C	2.16	TOTAL DESIGN LOAD (AMPS)	21

Figure 5.3.10 | New Panel 2P1A

Sample Calculations for New Sizing:

Brach Circuit Breaker for Motor (Sample for Elevator No. 2):

MCA (NEC 2005 430.250) = 65A * 1.25 (First Motor) = 81.25A

MOPD (NEC 2005 430.52) = 250% (Inverse Time Breaker)

2.5 * 65A = 162.5A

BREAKER SIZE: 150A

WIRE SIZE: (3) #4 Conductors

Transformer (Sample for Panel 1KN1):

Calculated Design Load: 23.3 KW, 28.8A

Transformer: 30 kVA

Secondary Protection: 83.3*1.25 = 104.1A [110A] (NEC Table 450.3 (B) = 125%)

Primary Protection: 36.1*2.5 = 90.25A [100A] (NEC Table 450.3 (B) = 250%)

*Feeder Calculation (From MSB1 to BNDP1) *Not the size used for cost comparison*

Design Load (Includes Growth) = 333A

Feeder Size = 400 MCM THW Copper in 3" Conduit (335A Capacity)

Cost Analysis:

The cost comparison between the new and existing systems was completed using *R.S. Means 2008 Electrical Cost Data*. The existing system from the most recent set of drawings is designed and sized for the original contract, which was a guaranteed maximum price (GMP). Because of this, all equipment and feeders were grossly oversized. Feeders were sized to match bus size. In order for the cost estimate to provide comparable results, this same method was utilized. The bus sizes have all been resized based on the new panel demand loads, however, greatly reducing the feeder sizes.

As noted previously, the utility transformer has not been included in this analysis because it is the responsibility of Duquesne Light. Additionally, feeders N, O, P, and Q have been omitted due to insignificant lengths.

The cost comparison is broken down in the following table:

Table 5.3.3: Electrical System Redesign - 208/120V to 480/277V - Cost Analysis

PANELS

Label	Load (KW)	Ex. Size (A)	Ex. Cost	New Size (A)	New Cost
MSB1	-	3000	$40,600.00	1600	$26,100.00
MSB2	NO CHANGE IN SIZE				
BNDP1	205.2	400	$1,750.00	100	$900.00
BNDP2	9.8	1200	$5,275.00	400	$1,750.00
1KN1	23.2	400	$3,125.00	100	$1,300.00
1KN2	NO CHANGE IN SIZE				
2P1	30.4	225	$1,175.00	100	$900.00
2P1A	NA	NA	NA	60	$700.00
		Subtotal =	$48,800.00	Subtotal =	$30,350.00

FEEDERS — Per 100' — (All feeders 75 C type THWN)

Label	Length (ft)	No. Wires	Ex. Size	Ex. Cost/Unit	Ex. Cost	New Size	New Cost/Unit	New Cost
A	30	4	(4) 500	$1,550.00	$7,440.00	(4) 500	$1,550.00	$7,440.00
B	35	4	4/0	$755.00	$1,063.04	3	$244.00	$343.55
C	129	4	(2) 4/0	$755.00	$7,773.48	2/0	$505.00	$2,599.74
D	248	4	(2) 250	$870.00	$17,226.00	3/0	$620.00	$6,138.00
E	76	4	500	$1,550.00	$4,705.80	1	$350.00	$1,062.60
F	190	4	350	$1,150.00	$8,753.80	2	$291.00	$2,215.09
G	242	4	(2) 3/0	$620.00	$12,003.20	2	$291.00	$2,816.88
H	15	4	(4) 350	$1,150.00	$2,760.00	(2) 3/0	$620.00	$744.00
I	15	4	(2) 3/0	$620.00	$744.00	3	$244.00	$146.40
J	35	4	350	$1,150.00	$1,610.00	4	$209.00	$292.60
K	35	4	350	$1,150.00	$1,610.00	4	$209.00	$292.60
L	35	4	350	$1,150.00	$1,610.00	4	$209.00	$292.60
M	35	4	350	$1,150.00	$1,610.00	6	$152.00	$212.80
				Subtotal =	$68,909.32		Subtotal =	$24,596.86

OTHER

Item	Existing	Existing Cost	New Size	New Cost
1TKN1	NA	NA	30 kVA	$3,425.00
2TP1A	NA	NA	9 kVA	$2,200.00
			Subtotal =	$5,625.00

Existing System Total =	$117,709.32
New System Total =	$60,571.86
COST DIFFERENCE =	$57,137.46

System Conversion Conclusion:

As shown in Table 5.3.3, converting MSB1 and its connected loads to a 480/277V system saves a significant amount of money. For a project that is trying to reduce the bottom line, this change seems to be a viable option. The tabulated data does not include further cost savings that would result from a reduction of individual breakers for branch circuits.

The second factor that must be considered in the conversion of this system is the loss of redundancy provided by the collector bus. Since the system includes a substantial emergency generator and the system does not include critical loads, it is my opinion that using a 480/277V system for switchboard MSB1 is an appropriate choice for this project.

4. PROTECTIVE DEVICE COORDINATION STUDY and FAULT CURRENT ANALYSIS

As a sample calculation, a protective device coordination study and a fault current analysis was performed for a selected path through the system. The calculations that follow summarize these two procedures. That path is as follows:

Utility Transformer > Main Switchboard (MSB1) > Distribution Panel (1NDP1) > End-Use Panel (1N1)

The results show that the currently designed system uses has equipment specified which, in one case, is less than that required by the calculations. Branch circuit panelboard 1TN1 requires 25000 AIC but the specified equipment is rated at 22,000 AIC. It is likely that a fault current analysis was not conducted for the production of this set of documents.

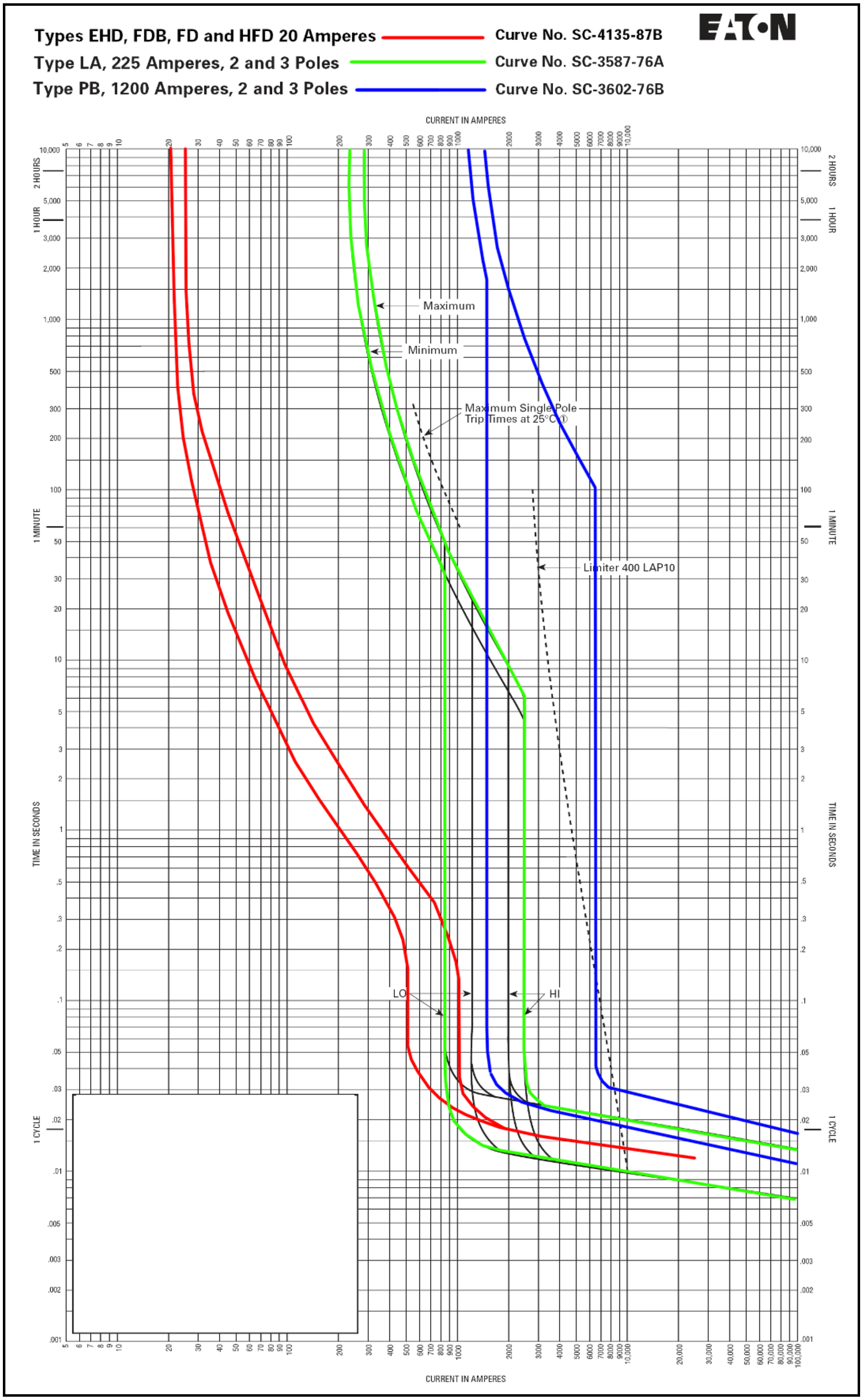

Figure 5.4.1 | Protective Device Coordination Study

Table 5.4.1: Summary Results of Fault Analysis			
Point	Location	Available Fault (A)	Standard Breaker Rating (A)
A	Utility Company Secondary	41630	42000
B	Switchboard (MSB2)	40197	42000
C	Distribution Panel (1NDP1)	34195	42000
D	End Use Panel (1N1)	24599	25000

Table 5.4.2: Fault Current Analysis (Per Unit Method)						
	System Voltage	= 208				
	Base KVA	= 10000				
	Utility Company Available Fault	= 100000000	ΣX	ΣR	ΣZ	I_{sc} (A)
Utility Primary						
	$X_{(p.u.)}$ = KVA_{base} / Utility S.C. KVA	= 0.0001	0.000	0.000	0.000	**277572245**
	$R_{(p.u.)}$	= 0.0000				
Transformer Secondary						
%Z = 5.00	$X_{(p.u.)}$ = %X * KVA_{base} / 100 * KVA_{xfrmr}	= 0.5951	0.595	0.301	0.667	**41630**
X/R = 1.98	$R_{(p.u.)}$ = %R * KVA_{base} / 100 * KVA_{xfrmr}	= 0.3005				
%X = 4.46						
%R = 2.25						
kVA = 750						
Switchboard MSB1						
Wire = 500	X = (L/1000) * X_L * (1/Sets), $X_{(p.u.)}$	= 0.0202	0.615	0.313	0.691	**40197**
Length = 15	R = (L/1000) * R * (1/Sets), $R_{(p.u.)}$	= 0.0127				
Sets = 8						
X = 0.047						
R = 0.029						
Panel Board 1NDP1						
Wire = 400	X = (L/1000) * X_L * (1/Sets)), $X_{(p.u.)}$	= 0.0991	0.714	0.385	0.812	**34195**
Length = 35	R = (L/1000) * R * (1/Sets), $R_{(p.u.)}$	= 0.0720				
Sets = 4						
X = 0.049						
R = 0.036						
Panel Board 1N1						
Wire = 4/0	X = (L/1000) * X_L * (1/Sets)), $X_{(p.u.)}$	= 0.2068	0.921	0.652	1.128	**24599**
Length = 18	R = (L/1000) * R * (1/Sets), $R_{(p.u.)}$	= 0.2663				
Sets = 1						
X = 0.050						
R = 0.064						