Electrical Depth

Introduction

The existing electrical system for each space redesigned in my lighting depth had to be adjusted accordingly to the new design. The following electrical depth will illustrate how these modifications were accommodated.

In addition to adjusting the existing electrical distribution to these spaces, a study was done to evaluate the determine feasibility of implementing a photo voltaic array on the roof of this building. A second study was done to compare standard transformers versus energy efficient ones.

Existing System

The Art & Visual Technology Building utilizes simple radial distribution at 480Y/277V, 3ϕ, 4W. It originates at the 2000A switchboard, which is located in the lower level main electrical room. The main switchboard has ten internal circuit breakers; two are dedicated to the automatic transfer switches, six go to distribution panels throughout the building and the final two are dedicated to each elevator. There are also four spaces left open in the switchboard with frame sizes ranging from 250A to 600A. Distribution is divided into panels that feed the North end of the building and those that feed the South. On the lower level, the main electric room feeds the South end of the building, while there is an electrical closet that feeds the North. On the floors above, electrical closets located in North and South ends of building feed their respective end. Each closet contains 480Y/277V 3ϕ, 4W panels, transformers and 208Y/120 3ϕ, 4W panels. Emergency power is supplied from an 80kW diesel generator and is integrated into normal building power thru automatic transfer switches

Main Entrance Courtyard

Fed from the same panel as the entry lobby, the lighting circuits at the main entrance façade also have a great distance for the conductors to run. One of the LED fixtures and recessed step lights both are low-voltage, with integral transformers, and require 120v power.

Branch Circuit Redesign

Please refer to the proceeding panelboard and power plan for additional information.

Panel L2N Circuit 6

6 "G" fixtures * 118 input watts/fixture = 708 W

2 "H" fixtures * 54 input watts/fixture = 108 W

4 "P" Fixtures * 13 input watts/fixture = 52W

Total watts = 868W/ .9PF = 964VA

964VA/277V = 3.5A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit EMT

**Note: 20A*277V * 80% de-rating = 4,432 W Maximum allowed*

Voltage Drop Calculation

$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	277
power factor	0.9
Length (ft)	220
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.749
Current (A)	3.5
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	2.693
% V_{drop}	**0.972**

0.972% < 3% maximum per NEC recommendations

Panel R2NA Circuit 45

6 "I" fixtures * 20 input watts/fixture = 120 W

43 "J" fixtures * 6 input watts/fixture = 258 W

3 "O" Fixtures * 280 input watts/fixture = 840W

1029W/1.0 PF = 1029VA

1029VA/120 V = 8.58A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit

**Note: 20A*120V * 80% de-rating = 1,920 W Maximum allowed*

Voltage Drop Calculation

$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	120
power factor	1
Length (ft)	205
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.917
Current (A)	8.6
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	6.759
% V_{drop}	**5.633**

3.177% > 3% maximum per NEC recommendations

Resize to #10

Circuit Voltage	120
power factor	1
Length (ft)	205
Wire Size	#10
$V_{drop/(1000\ A\ ft)}$	1.2
Current (A)	8.6
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	4.231
% V_{drop}	**3.526**

3.526% > 3% maximum per NEC recommendations

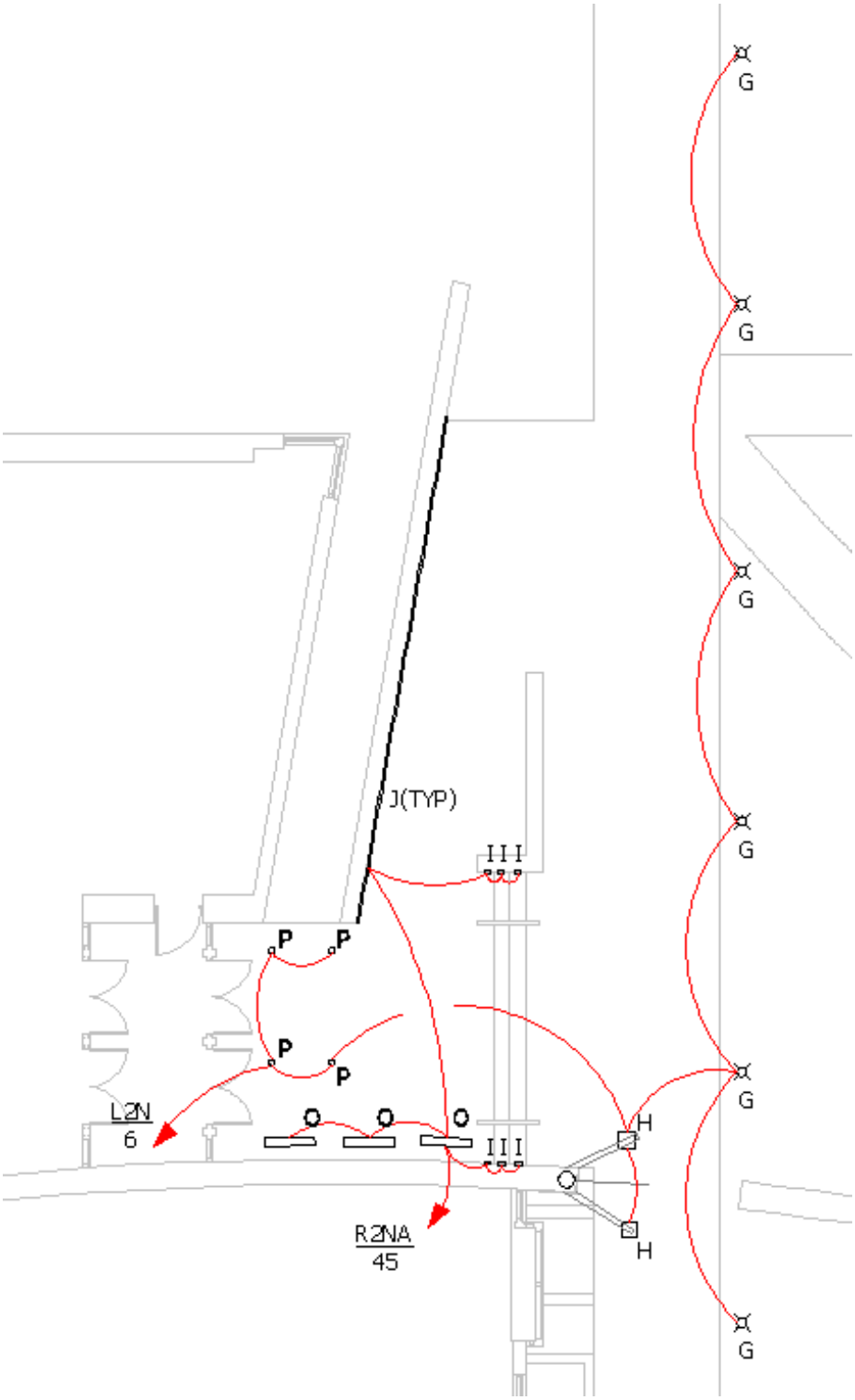
Resize to #10

Circuit Voltage	120
power factor	1
Length (ft)	205
Wire Size	#8
$V_{drop/(1000\ A\ ft)}$	0.75
Current (A)	8.6
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	2.645
% V_{drop}	**2.204**

2.204% < 3% maximum per NEC recommendations

-> **2#8 Copper THWN, 20A single pole breaker, ¾" conduit**

New Lighting Power Plan



** Note: See Appendix G for a 1/8" = 1'-0" Plan*

Existing L2N Panelboard

PANELBOARD: L2N		BUS RATING:							60	A		MAIN OCP OR	
MIN AIC:		VOLTAGE:							208	120	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:							SURFACE			WIRES:	5
LOCATION:		NOTES:											
				LOAD, VA									
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	CIRCUIT DESIGNATION
West Corridor	1	20	1	1100									
West Corridor	1	20	2			1000							
East Corridor & Elevator Lobby	1	20	3					900					
East Corridor	1	20	4	700									
Student Lounge	1	20	5			300							
Exterior Lighting	1	20	6					600					
Exterior Lighting	1	20	7	600									
LTG RM 1001	1	20	8			775							
	1	20	9										
	1	20	10										
	1	20	11										
	1	20	12										
	1	20	13										
	1	20	14										
	1	20	15										
	1	20	16										
	1	20	17										
	1	20	18										
	1	20	19										
	1	20	20										
	1	20	21										
PHASE CONNECTED LOAD, VA					2400		2075		1500				
PHASE BALANCE					20.50%		4.18%		-24.69%				
TOTAL CONNECTED LOAD, VA		5975											
FUTURE GROWTH - 25%		1494											
TOTAL + FUTURE LOAD, VA		7469											
TOTAL CURRENT, A		21											
DESIGN CURRENT, A		26											
MINIMUM MAIN OCP		100											

Existing R2NA Panelboard

PANELBOARD: R2NA		BUS RATING:						400 A		MAIN OCP OR MLO				
MIN AIC:		VOLTAGE:						208 120 V		PHASE(S):		3		
NEMA 1 ENCLOSURE		MOUNTING:						SURFACE		WIRES:		4		
LOCATION:		NOTES:						200% NEUTRAL						
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT	ϕA		ϕB		ϕC		CKT#	TRIP	P	CH CIRCUIT DESIGNATION	
Recept - WC	1	20	1	720	784					2	20	1	SOUND BOOTH	
Recept - RM 1126 / 1127	1	20	3			1080				4	20	1	SPARE	
Recept - WC	1	20	5					720		6	20	1	SPARE	
Recept - Corridor (Flat Panel Display)	1	20	7	600						8	20	1	SPARE	
Recept - Corridor	1	20	9			900	660			10	20	1	Recept - RM 1006	
Recept - RM 1004	1	20	11					360	600	12	20	1	Recept - RM 1006	
Recept - RM 1004	1	20	13	720	600					14	20	1	Recept - RM 1006	
Recept - RM 1004	1	20	15			720	600			16	20	1	Recept - RM 1006	
Recept - RM 1004 (AV)	1	20	17					840	600	18	20	1	Recept - RM 1006	
Projector - RM 1004	1	20	19	300	360					20	20	1	Recept - RM 1006	
Recept - Corridor (Flat Panel Display)	1	20	21			600	1200			22	20	1	Recept - RM 1006	
Recept - Corridor	1	20	23					360	1200	24	20	1	Recept - RM 1006	
EF-4	1	20	25	528	912					26	20	1	Recept - RM 1006	
Recept - Proj. RM 1007	1	20	27			300	912			28	20	1	Recept - RM 1006	
Recept - Proj. RM 1007	1	20	29					300	900	30	20	1	Recept - RM 1005	
Recept - RM 1007	1	20	31	360	900					32	20	1	Recept - RM 1005	
Recept - RM 1007	1	20	33			540	360			34	20	1	Recept - RM 1005	
Recept - RM 1007	1	20	35					540	300	36	20	1	Projector - RM 1005	
Recept - RM 1007	1	20	37	540	750					38	20	1	LTG - RM 1005	
Recept - RM 1007 (AV)	1	20	39			840	1875			40	20	1	LTG - RM 1021	
Recept - RM 1125	1	20	41					180	1875	42	20	1	LTG - RM 1022	
Recept - RM 1007 (AV)	1	20	43	840	1875					44	20	1	LTG - RM 1023	
	1	20	45				0			46	20	1	SPARE	
	1	20	47						1125	48	20	1	LTG - RM 1004	
	1	20	49		180					50	20	1	Trap Priming Cabinet	
	1	20	51							52	20	1		
	1	20	53							54	20	1		
	1	20	55							56	20	1		
	1	20	57							58	20	1		
	1	20	59							60	20	1		
	1	20	61							62	20	1		
	1	20	63							64	20	1		
	1	20	65							66	20	1		
	1	20	67							68	20	1		
	1	20	69							70	20	1		
	1	20	71							72	20	1		
	1	20	73		5260					74				
	1	20	75				4792			76	150	3	PNL R2NF	
	1	20	77						4008	78				
	1	20	79		7050					80				
	1	20	81				6450			82	80	3	PNL R2ND	
	1	20	83						5670	84				
PHASE CONNECTED LOAD, VA					23279		21829		19578					
PHASE BALANCE					7.96%		1.24%		-9.20%					

TOTAL CONNECTED LOAD, VA	64686
FUTURE GROWTH - 25%	16172
TOTAL + FUTURE LOAD, VA	80858
TOTAL CURRENT, A	224
DESIGN CURRENT, A	281
MINIMUM MAIN OCP	400

Redesigned L2N Panelboard

PANELBOARD: L2N		BUS RATING:								60	A		MAIN OCP	60A MCB
MIN AIC:		VOLTAGE:								208	120	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:								SURFACE			WIRES:	5
LOCATION:		NOTES:												
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	CIRCUIT DESIGNATION	
West Corridor	1	20	1	747										
West Corridor	1	20	2			952								
East Corridor & Elevator Lobby	1	20	3					644						
East Corridor	1	20	4	652										
Lobby Lighting	1	20	5			1317								
Exterior Lighting	1	20	6					964						
Spare	1	20	7	0										
Lobby Cove Lighting	1	20	8			348								
	1	20	9											
	1	20	10											
	1	20	11											
	1	20	12											
	1	20	13											
	1	20	14											
	1	20	15											
	1	20	16											
	1	20	17											
	1	20	18											
	1	20	19											
	1	20	20											
	1	20	21											
PHASE CONNECTED LOAD, VA					1399		2617		1608					
PHASE BALANCE					-25.37%		39.60%		-14.22%					
TOTAL CONNECTED LOAD, VA		5624												
FUTURE GROWTH - 25%		1406												
TOTAL + FUTURE LOAD, VA		7030												
TOTAL CURRENT, A		20												
DESIGN CURRENT 1.25 CONT. Factor		24												
MINIMUM MAIN OCP		60												

*Note red highlighted circuits correspond to the lobby and blue highlighted correspond to the main façade.

Main Overcurrent Protection

60A breaker

New Feeder Size

(4) #6 and (1) #10 ground in 1" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. THWN Copper wire rated for 75°C.

Redesigned L2N Panelboard

PANELBOARD: R2NA		BUS RATING:						400 A		MAIN OCP: 3P 300A MCI				
MIN AIC:		VOLTAGE:						208 120 V		PHASE(S):		3		
NEMA 1 ENCLOSURE		MOUNTING:						SURFACE		WIRES:		4		
LOCATION:		NOTES:												
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT	ϕA		ϕB		ϕC		CKT#	TRIP	P	NCH CIRCUIT DESIGNATION	
Recept - WC	1	20	1	720	784					2	20	1	SOUND BOOTH	
Recept - RM 1126 / 1127	1	20	3			1080				4	20	1	SPARE	
Recept - WC	1	20	5					720		6	20	1	SPARE	
Recept - Corridor (Flat Panel Display)	1	20	7	600						8	20	1	SPARE	
Recept - Corridor	1	20	9			900	660			10	20	1	Recept - RM 1006	
Recept - RM 1004	1	20	11					360	600	12	20	1	Recept - RM 1006	
Recept - RM 1004	1	20	13	720	600					14	20	1	Recept - RM 1006	
Recept - RM 1004	1	20	15			720	600			16	20	1	Recept - RM 1006	
Recept - RM 1004 (AV)	1	20	17					840	600	18	20	1	Recept - RM 1006	
Projector - RM 1004	1	20	19	300	360					20	20	1	Recept - RM 1006	
Recept - Corridor (Flat Panel Display)	1	20	21			600	1200			22	20	1	Recept - RM 1006	
Recept - Corridor	1	20	23					360	1200	24	20	1	Recept - RM 1006	
EF-4	1	20	25	528	912					26	20	1	Recept - RM 1006	
Recept - Proj. RM 1007	1	20	27			300	912			28	20	1	Recept - RM 1006	
Recept - Proj. RM 1007	1	20	29					300	900	30	20	1	Recept - RM 1005	
Recept - RM 1007	1	20	31	360	900					32	20	1	Recept - RM 1005	
Recept - RM 1007	1	20	33			540	360			34	20	1	Recept - RM 1005	
Recept - RM 1007	1	20	35					540	300	36	20	1	Projector - RM 1005	
Recept - RM 1007	1	20	37	540	750					38	20	1	LTG - RM 1005	
Recept - RM 1007 (AV)	1	20	39			840	1875			40	20	1	LTG - RM 1021	
Recept - RM 1125	1	20	41					180	1875	42	20	1	LTG - RM 1022	
Recept - RM 1007 (AV)	1	20	43	840	1875					44	20	1	LTG - RM 1023	
Exterior Lighting	1	20	45			1030	0			46	20	1	SPARE	
	1	20	47						1125	48	20	1	LTG - RM 1004	
	1	20	49		180					50	20	1	Trap Priming Cabinet	
	1	20	51							52	20	1		
	1	20	53							54	20	1		
	1	20	55							56	20	1		
	1	20	57							58	20	1		
	1	20	59							60	20	1		
	1	20	61							62	20	1		
	1	20	63							64	20	1		
	1	20	65							66	20	1		
	1	20	67							68	20	1		
	1	20	69							70	20	1		
	1	20	71							72	20	1		
	1	20	73		5260					74				
	1	20	75				4792			76	150	3	PNL R2NF	
	1	20	77						4008	78				
	1	20	79		7050					80				
	1	20	81				6450			82	80	3	PNL R2ND	
	1	20	83						5670	84				
PHASE CONNECTED LOAD, VA					23279		22859		19578					
PHASE BALANCE					6.27%		4.35%		-10.62%					

TOTAL CONNECTED LOAD, VA	65716
FUTURE GROWTH - 25%	16429
TOTAL + FUTURE LOAD, VA	82145
TOTAL CURRENT, A	228
DESIGN CURRENT, A (1.0 Demand Fac	228
MINIMUM MAIN OCP	300

Main Overcurrent Protection

300A breaker

New Feeder Size

(4) #350 MCM and (1) #4 ground in 3" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. THWN Copper wire rated for 75°C.

Entry Lobby

The entry lobby was divided into two circuits on the basis of constructability. The main circuit feeds all the fixtures on the entry level and the continuous wall sconce on the stairwell column. The second circuit feeds the stairwell cove for the all three levels of the building. One important issue electrically with the lobby was the long length of conductors for each of the circuits. However, by each circuit being at 277V, voltage drop turned out to be not become an issue. Since this is a public space, the primary control for lighting will be done via a time-clock while a manual switch is located remotely by the gallery support area in the NW corner of the lobby.

Branch Circuit Redesign

Please refer to the proceeding panelboard and power plan for additional information.

Panel L2N Circuit 5

21 "C" fixtures * 33 input watts/fixture = 693 W

8 "D" fixtures * 33 input watts/fixture = 264 W

10 "E" fixtures * 36 input watts/fixture = 360 W

Total Watts = 1,317 W/.90PF = 1463VA

1463VA/277V = 5.3A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit EMT

**Note: 20A*277V * 80% de-rating = 4,432 W Maximum allowed*

Voltage Drop Calculation

$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	277
power factor	0.9
Length (ft)	165
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.749
Current (A)	5.3
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	3.059
% V_{drop}	**1.104**

1.104% < 3% maximum per NEC recommendations

Panel L2N Circuit 8

12 "F" fixtures * 29 input watts/fixture = 348 W

348W/.90 PF = 387VA

387VA/277 V = 1.4A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit

**Note: 20A*277V * 80% de-rating = 4,432 W Maximum allowed*

Voltage Drop Calculation

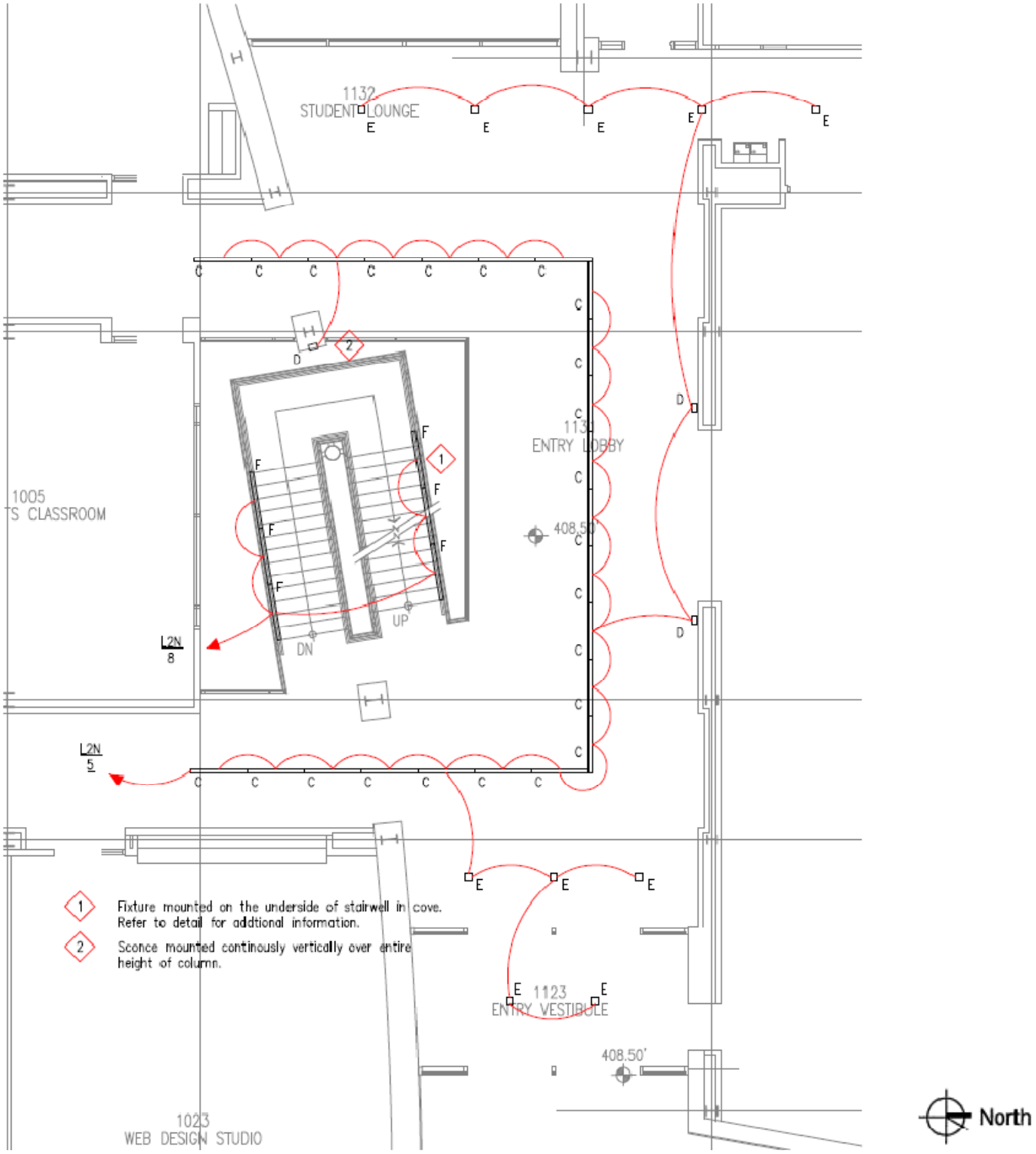
$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	277
power factor	0.9
Length (ft)	140
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.749
Current (A)	1.4
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	0.686
% V_{drop}	**0.248**

0.248% < 3% maximum per NEC recommendations

New Lighting Power Plan



** Note: See Appendix H for a 1/8" = 1'-0" Plan*

Existing L2N Panelboard

PANELBOARD: L2N		BUS RATING:								60	A		MAIN OCP OR	
MIN AIC:		VOLTAGE:								208	120	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:								SURFACE			WIRES:	5
LOCATION:		NOTES:												
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	CIRCUIT DESIGNATION	
West Corridor	1	20	1	1100										
West Corridor	1	20	2			1000								
East Corridor & Elevator Lobby	1	20	3					900						
East Corridor	1	20	4	700										
Student Lounge	1	20	5			300								
Exterior Lighting	1	20	6					600						
Exterior Lighting	1	20	7	600										
LTG RM 1001	1	20	8			775								
	1	20	9											
	1	20	10											
	1	20	11											
	1	20	12											
	1	20	13											
	1	20	14											
	1	20	15											
	1	20	16											
	1	20	17											
	1	20	18											
	1	20	19											
	1	20	20											
	1	20	21											
PHASE CONNECTED LOAD, VA					2400		2075		1500					
PHASE BALANCE					20.50%		4.18%		-24.69%					
TOTAL CONNECTED LOAD, VA		5975												
FUTURE GROWTH - 25%		1494												
TOTAL + FUTURE LOAD, VA		7469												
TOTAL CURRENT, A		21												
DESIGN CURRENT, A		26												
MINIMUM MAIN OCP		100												

Redesigned L2N Panelboard

PANELBOARD: L2N		BUS RATING:							60	A		MAIN OCP	60A MCB
MIN AIC:		VOLTAGE:							208	120	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:							SURFACE			WIRES:	5
LOCATION:		NOTES:											
				LOAD, VA									
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	CIRCUIT DESIGNATION
West Corridor	1	20	1	747									
West Corridor	1	20	2			952							
East Corridor & Elevator Lobby	1	20	3					644					
East Corridor	1	20	4	652									
Lobby Lighting	1	20	5			1317							
Exterior Lighting	1	20	6					660					
Spare	1	20	7	0									
Lobby Cove Lighting	1	20	8			348							
	1	20	9										
	1	20	10										
	1	20	11										
	1	20	12										
	1	20	13										
	1	20	14										
	1	20	15										
	1	20	16										
	1	20	17										
	1	20	18										
	1	20	19										
	1	20	20										
	1	20	21										
PHASE CONNECTED LOAD, VA					1399		2617		1304				
PHASE BALANCE					-21.11%		47.58%		-26.47%				
TOTAL CONNECTED LOAD, VA		5320											
FUTURE GROWTH - 25%		1330											
TOTAL + FUTURE LOAD, VA		6650											
TOTAL CURRENT, A		18											
DESIGN CURRENT 1.25 CONT. Factor		23											
MINIMUM MAIN OCP		60											

**Note Red Highlighted circuits correspond to the entry lobby while blue highlighted circuits correspond to the main courtyard.*

Main Overcurrent Protection

60A breaker

New Feeder Size

(4) #6 and (1) #10 ground in 1" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. THWN Copper wire rated for 75°C.

Painting Studio

The modification of the existing artificial and natural lighting systems led to necessary changes for the electrical demands for this space. Most notably is the added load of the motorized shades. The motors were estimated of having an electrical load of 150kW since electrical specifications were unavailable.

Branch Circuit Redesign

Please refer to the proceeding panelboards and power plan for additional information.

Max Dimmer panel load

9 Type "A" fixtures * 62W/fixture = 558W

558W/1.00 PF = 558VA

558VA/277 V = 2.1A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit EMT

**Note: 20A*120V * 80% de-rating = 1,920 W Maximum allowed*

Voltage Drop Calculation

$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	120
power factor	0.9
Length (ft)	85
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.749
Current (A)	2.1
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	0.624
% V_{drop}	**0.520**

0.520% < 3% maximum per NEC recommendations

Motor Load R3SA Circuit 46

9 Motors * 150W/motor = 1450W

1450W/.80 PF = 1813VA

1813VA/120 V =15.1A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit EMT

**Note: 20A*120V * 80% de-rating = 1,920 W Maximum allowed*

Voltage Drop Calculation

$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	120
power factor	0.8
Length (ft)	85
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.57
Current (A)	15.1
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	4.030
% V_{drop}	**3.358**

3.358% > 3% maximum per NEC recommendations

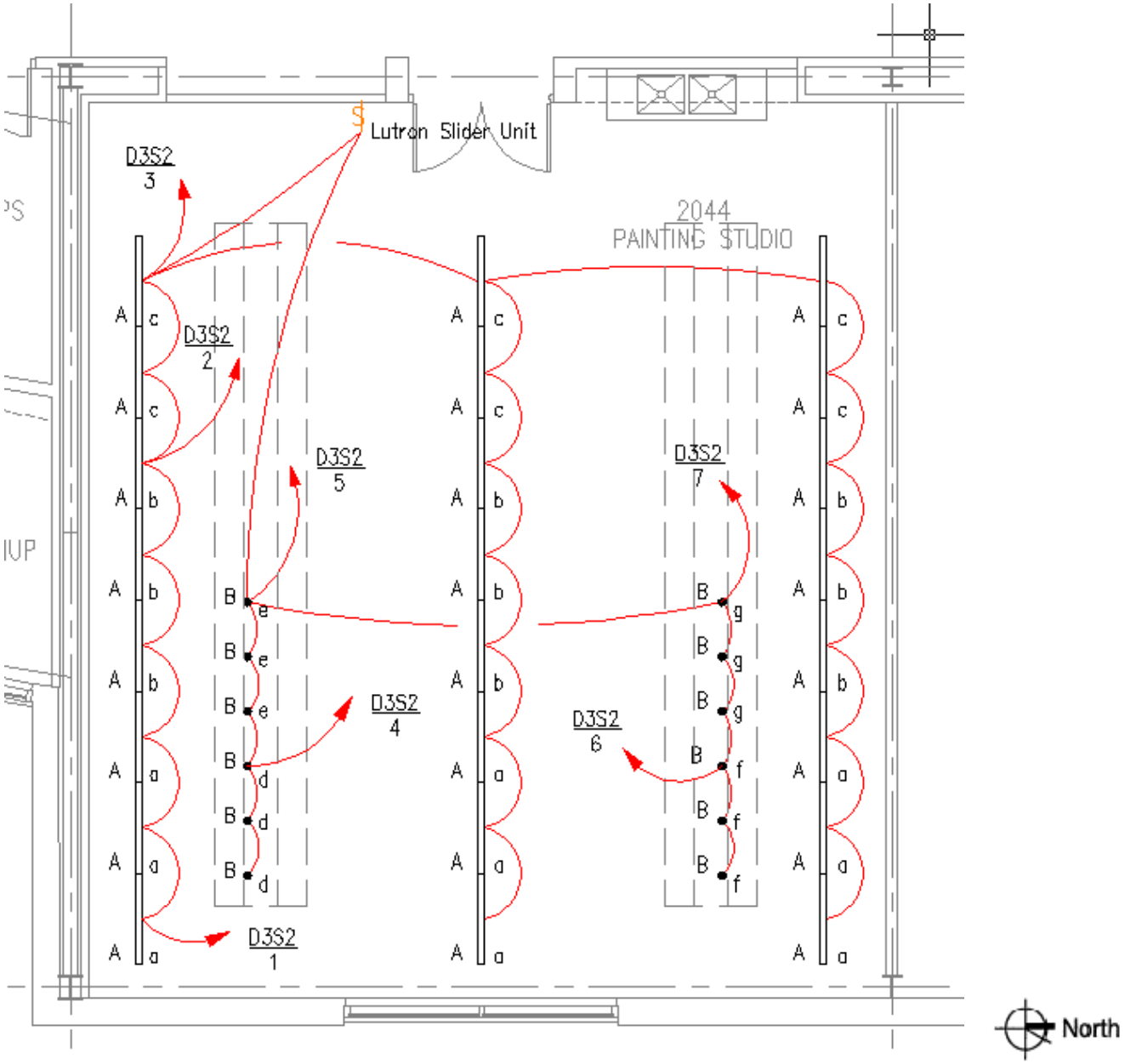
Resize using #10 Wire

Circuit Voltage	120
power factor	0.8
Length (ft)	85
Wire Size	#10
$V_{drop/(1000\ A\ ft)}$	0.993
Current (A)	15.1
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	2.549
% V_{drop}	**2.124**

2.124% < 3% maximum per NEC recommendations

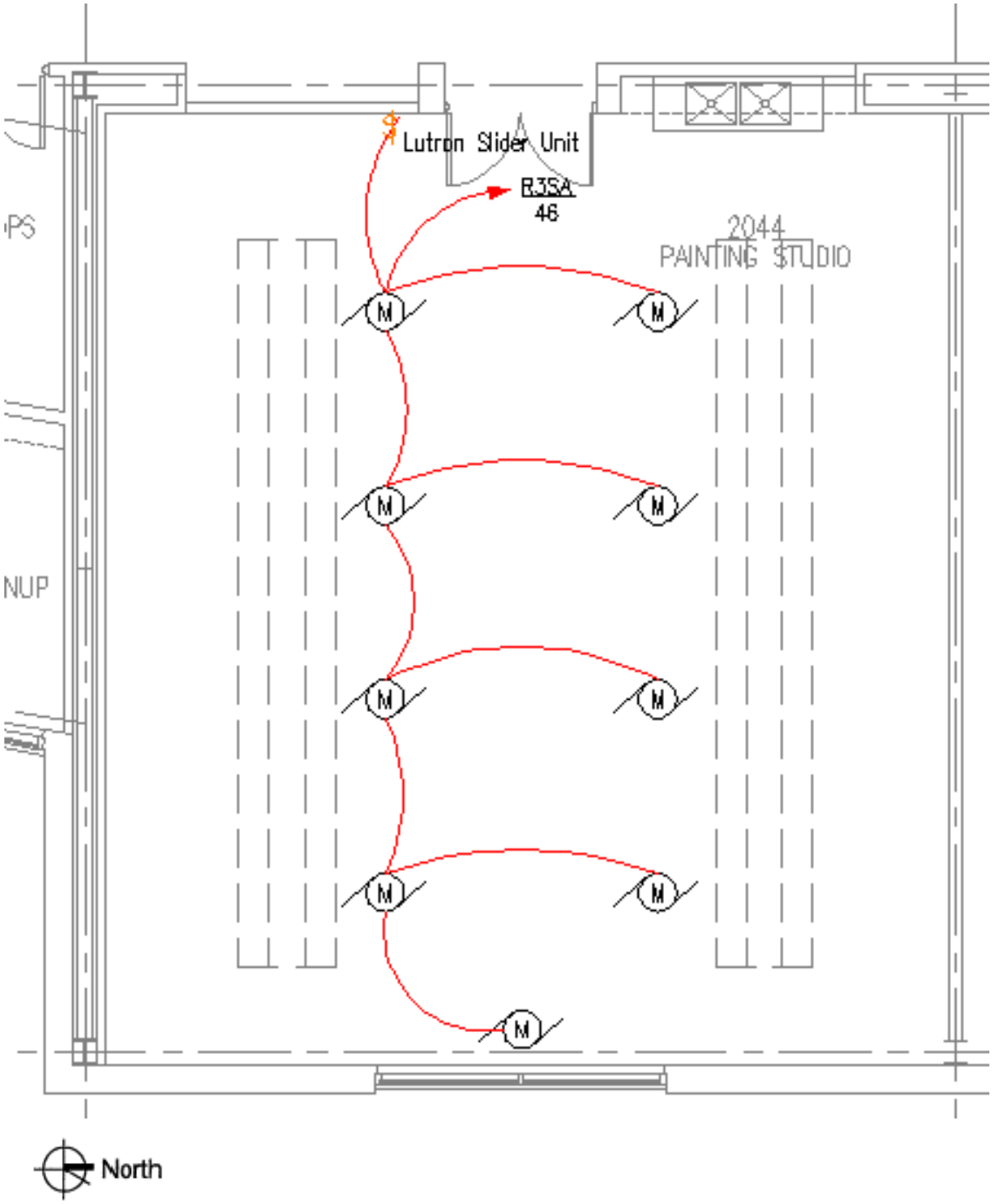
->2#12 Copper THWN, 20A single pole breaker, ¾" Conduit EMT

New Lighting Plan



** Note: See Appendix I for a 1/8" = 1'-0" Plan*

New Power Plan



** Note: See Appendix I for a 1/8" = 1'-0" Plan*

Existing H3SB Panelboard

PANELBOARD: H3SB		BUS RATING:								100	A		MAIN OCP OR MLO: MLO	
MIN AIC:		VOLTAGE:								480	277	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:								SURFACE			WIRES:	4
LOCATION:		NOTES:												
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	BRANCH CIRCUIT DESIGNATION	
LTG - Offices	1	20	1	2150						2	20	1		
LTG - RM 2037 & 2045	1	20	3			400				4	20	1		
LTG -RM 2044	1	20	5					1300		6	20	1		
LTG - RM 2046	1	20	7	1300						8	20	1		
LTG - RM 2035	1	20	9			2050				10	20	1		
	1	20	11							12	20	1		
	1	20	13							14	20	1		
	1	20	15							16	20	1		
	1	20	17							18	20	1		
	1	20	19							20	20	1		
	1	20	21							22	20	1		
	1	20	23							24	20	1		
	1	20	25							26	20	1		
	1	20	27							28	20	1		
	1	20	29							30	20	1		
PHASE CONNECTED LOAD, VA					3450		2450		1300					
PHASE BALANCE					43.75%		2.08%		-45.83%					
TOTAL CONNECTED LOAD, VA		7200												
FUTURE GROWTH - 25%		1800												
TOTAL + FUTURE LOAD, VA		9000												
TOTAL CURRENT, A		11												
DESIGN CURRENT, A		14												
MINIMUM MAIN OCP		60												

Existing R3SA Panelboard

PANELBOARD: R3SA		BUS RATING:								400	A		MAIN OCP OR MLO: 3P250A MCB	
MIN AIC:		VOLTAGE:								208	120	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:								SURFACE			WIRES:	5
LOCATION:		NOTES:								200% NEUTRAL				
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	BRANCH CIRCUIT DESIGNATION	
Recept - RM 2041	1	20	1	720	600					2	20	1	Recept - RM 2034	
Recept - RM 2040	1	20	3			720	600			4	20	1	Recept - RM 2034	
Recept - Corridor	1	20	5					540	360	6	20	1	Recept - RM 2034	
Recept - RM 2039	1	20	7	720	840					8	20	1	Recept - RM 2033	
Recept - RM 2038	1	20	9			720	840			10	20	1	Recept - RM 2031	
Recept - RM 2036	1	20	11					720	840	12	20	1	Recept - RM 2029	
Recept - RM 2035	1	20	13	780	840					14	20	1	Recept - RM 2032	
Recept - RM 2035	1	20	15			480	840			16	20	1	Recept - RM 2030	
Recept - RM 2035	1	20	17					780	840	18	20	1	Recept - RM 2028	
Recept - RM 2035	1	20	19	780	1140					20	20	1	Recept - RM 2027	
Recept - Corridor	1	20	21			540	840			22	20	1	Recept - RM 2025	
Recept - RM 2037/2154	1	20	23					720	840	24	20	1	Recept - RM 2023	
Recept - RM 2041	1	20	25	540	840					26	20	1	Recept - RM 2021	
Recept - RM 2040	1	20	27			540	840			28	20	1	Recept - RM 2024	
Recept - RM 2039	1	20	29					540	840	30	20	1	Recept - RM 2022	
Recept - RM 2038	1	20	31	540	300					32	20	1	Projector - RM 2026	
Recept - RM 2036	1	20	33			540	840			34	20	1	Recept - RM 2026	
Motorized Proj. Screen	1	20	35					300	840	36	20	1	Recept - RM 2020	
Recept - RM 2026 (AV)	1	20	37	840	300					38	20	1	Projector - RM 2026	
LTG - RM 2044	1	20	39			1500	540			40	20	1	Recept - RM 2026	
LTG - RM 2044	1	20	41					1500	840	42	20	1	Recept - RM 2026	
LTG - RM 2044	1	20	43	1500	840					44	20	1	Recept - RM 2026 (AV)	
Recept - Roof	1	20	45			180	938			46	20	1	LTG - RM 2044	
SPARE	1	20	47					0	938	48	20	1	LTG - RM 2046	
LTG - RM 2045	1	20	49	750	938					50	20	1	LTG - RM 2046	
LTG - RM 2045	1	20	51			750	938			52	20	1	LTG - RM 2044	
LTG - RM 2045	1	20	53					750	1125	54	20	1	LTG - RM 2046	
LTG - RM 2044	1	20	55	938	1125					56	20	1	LTG - RM 2046	
LTG - RM 2044	1	20	57			938	1125			58	20	1	LTG - RM 2046	
LTG - RM 2046	1	20	59					938	540	60	20	1	Recept - RM 2045	
LTG - RM 2046	1	20	61	938	720					62	20	1	Recept - RM 2045	
SPARE	1	20	63			0	864			64	20	1	CUH-7	
SPARE	1	20	65					0	180	66	20	1	Recept - Roof	
Recept - Flat Panel Display	1	20	67	600						68	20	1		
	1	20	69							70	20	1		
	1	20	71							72	20	1		
	1	20	73							74	20	1		
	1	20	75							76	20	1		
	1	20	77							78	20	1		
			79	3060						80	20	1		
PNL R3SB	3	100	81			2340				82	20	1		
			83					2460		84	20	1		
PHASE CONNECTED LOAD, VA					21188		18452		17430					
PHASE BALANCE					11.38%		-3.00%		-8.37%					
TOTAL CONNECTED LOAD, VA		57069												
FUTURE GROWTH - 25%		14267												
TOTAL + FUTURE LOAD, VA		71336												
TOTAL CURRENT, A		198												
DESIGN CURRENT, A		248												
MINIMUM MAIN OCP		250												

Redesigned H3SB Panelboard

PANELBOARD: H3SB		BUS RATING:							100	A		MAIN OCP OR MLO: 60A MCB		
MIN AIC:		VOLTAGE:							480	277	V	PHASE(S):		3
NEMA 1 ENCLOSURE		MOUNTING:							SURFACE			WIRES:		4
LOCATION:		NOTES:												
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	BRANCH CIRCUIT DESIGNATION	
LTG - Offices	1	20	1	2150						2	20	1		
LTG - RM 2037 & 2045	1	20	3			400				4	20	1		
Spare	1	20	5					0		6	20	1		
LTG - RM 2046	1	20	7	1300						8	20	1		
LTG - RM 2035	1	20	9			2050				10	20	1		
	1	20	11							12	20	1		
	1	20	13							14	20	1		
	1	20	15							16	20	1		
	1	20	17							18	20	1		
	1	20	19							20	20	1		
	1	20	21							22	20	1		
	1	20	23							24	20	1		
	1	20	25							26	20	1		
	1	20	27							28	20	1		
	1	20	29							30	20	1		
PHASE CONNECTED LOAD, VA					3450		2450		0					
PHASE BALANCE					75.42%		24.58%		-100.00%					
TOTAL CONNECTED LOAD, VA		5900												
FUTURE GROWTH - 25%		1475												
TOTAL + FUTURE LOAD, VA		7375												
TOTAL CURRENT, A		11												
DESIGN CURRENT, A (1.25 Cont. Factor)		14												
MINIMUM MAIN OCP		60												

Main Overcurrent Protection

60A breaker

New Feeder Size

(4) #6 and (1) #10 ground in 1" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. THWN Copper wire rated for 75°C.

Redesigned R3SA Panelboard

PANELBOARD: R3SA		BUS RATING:								400	A		MAIN OCP OR MLO: 3P200A MCB	
MIN AIC:		VOLTAGE:								208	120	V	PHASE(S):	3
NEMA 1 ENCLOSURE		MOUNTING:								SURFACE			WIRES:	5
LOCATION:		NOTES:								200% NEUTRAL				
				LOAD, VA										
BRANCH CIRCUIT DESIGNATION	P	TRIP	CKT#	ϕA		ϕB		ϕC		CKT#	TRIP	P	BRANCH CIRCUIT DESIGNATION	
Recept - RM 2041	1	20	1	720	600					2	20	1	Recept - RM 2034	
Recept - RM 2040	1	20	3			720	600			4	20	1	Recept - RM 2034	
Recept - Corridor	1	20	5					540	360	6	20	1	Recept - RM 2034	
Recept - RM 2039	1	20	7	720	840					8	20	1	Recept - RM 2033	
Recept - RM 2038	1	20	9			720	840			10	20	1	Recept - RM 2031	
Recept - RM 2036	1	20	11					720	840	12	20	1	Recept - RM 2029	
Recept - RM 2035	1	20	13	780	840					14	20	1	Recept - RM 2032	
Recept - RM 2035	1	20	15			480	840			16	20	1	Recept - RM 2030	
Recept - RM 2035	1	20	17					780	840	18	20	1	Recept - RM 2028	
Recept - RM 2035	1	20	19	780	1140					20	20	1	Recept - RM 2027	
Recept - Corridor	1	20	21			540	840			22	20	1	Recept - RM 2025	
Recept - RM 2037/2154	1	20	23					720	840	24	20	1	Recept - RM 2023	
Recept - RM 2041	1	20	25	540	840					26	20	1	Recept - RM 2021	
Recept - RM 2040	1	20	27			540	840			28	20	1	Recept - RM 2024	
Recept - RM 2039	1	20	29					540	840	30	20	1	Recept - RM 2022	
Recept - RM 2038	1	20	31	540	300					32	20	1	Projector - RM 2026	
Recept - RM 2036	1	20	33			540	840			34	20	1	Recept - RM 2026	
Motorized Proj. Screen	1	20	35					300	840	36	20	1	Recept - RM 2020	
Recept - RM 2026 (AV)	1	20	37	840	300					38	20	1	Projector - RM 2026	
----------	-	-	39			696	540			40	20	1	Recept - RM 2026	
Dimmer Panel D3S2	3	20	41					696	840	42	20	1	Recept - RM 2026	
----------	-	-	43	696	840					44	20	1	Recept - RM 2026 (AV)	
Recept - Roof	1	20	45			180	1688			46	20	1	Shade Motors RM 2044	
SPARE	1	20	47					0	938	48	20	1	LTG - RM 2046	
LTG - RM 2045	1	20	49	750	938					50	20	1	LTG - RM 2046	
LTG - RM 2045	1	20	51			750	0			52	20	1	Spare	
LTG - RM 2045	1	20	53					750	1125	54	20	1	LTG - RM 2046	
Spare	1	20	55	0	1125					56	20	1	LTG - RM 2046	
Spare	1	20	57			0	1125			58	20	1	LTG - RM 2046	
LTG - RM 2046	1	20	59					938	540	60	20	1	Recept - RM 2045	
LTG - RM 2046	1	20	61	938	720					62	20	1	Recept - RM 2045	
SPARE	1	20	63			0	864			64	20	1	CUH-7	
SPARE	1	20	65					0	180	66	20	1	Recept - Roof	
Recept - Flat Panel Display	1	20	67	600						68	20	1		
	1	20	69							70	20	1		
	1	20	71							72	20	1		
	1	20	73							74	20	1		
	1	20	75							76	20	1		
	1	20	77							78	20	1		
			79	3060						80	20	1		
PNL R3SB	3	100	81			2340				82	20	1		
			83					2460		84	20	1		
PHASE CONNECTED LOAD, VA					19446		16523		16626					
PHASE BALANCE					10.92%		-5.75%		-5.17%					
TOTAL CONNECTED LOAD, VA		52595												
FUTURE GROWTH - 25%		13149												
TOTAL + FUTURE LOAD, VA		65744												
TOTAL CURRENT, A		182												
DESIGN CURRENT, A		182												
MINIMUM MAIN OCP		200A												

Main Overcurrent Protection

200A Main circuit breaker

New Feeder Size

(4) #3/0 and (1) #6 ground in 2" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. Copper wire rated for 75° C.

New Dimmer Panel D3S2

NEMA 1 ENCLOSURE				MOUNTING:						SURFACE		WIRES:	5
LOCATION:				NOTES:									
				LOAD, VA									
RANCH CIRCUIT DESIGNATIO	P	TRIP	CK	ϕA		ϕB		ϕC		CKT#	TRIP	P	NCH CIRCUIT DESIGNATION
LTG - RM 2044	1	20	1	558						2	20	1	Space
LTG - RM 2044	1	20	3			558				4	20	1	Space
LTG - RM 2044	1	20	5					372		6	20	1	Space
LTG - RM 2044	1	20	7	150						8	20	1	Space
LTG - RM 2044	1	20	9			150				10	20	1	Space
LTG - RM 2044	1	20	11					150		12	20	1	Space
LTG - RM 2044	1	20	13	150						14	20	1	Space
Spare	1	20	15							16	20	1	Space
Spare	1	20	17							18	20	1	Space
Space	1	-	19							20	20	1	Space
Space	1	-	21							22	20	1	Space
Space	1	-	23							24	20	1	Space
PHASE CONNECTED LOAD, VA					858		708		522				
PHASE BALANCE					23.28%		1.72%		-25.00%				

TOTAL CONNECTED LOAD, VA	2088
FUTURE GROWTH - 10%	209
TOTAL + FUTURE LOAD, VA	2297
TOTAL CURRENT, A	6
DESIGN CURRENT, A (*1.25)	8
MINIMUM MAIN OCP	20

Main Overcurrent Protection

20A Main circuit breaker

New Feeder Size

(4) #12 and (1) #12 ground in 1" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. Copper wire rated for 75° C.

Exhibit Gallery

The existing designed utilized a dimmer panel for the control of the 120V track lighting while the suspended direct/indirect fixtures provided ambient light for the space were fed on 277V. Upon redesign, recessed low profile louvered fixtures provide ambient light and were added to the 120V dimmer panel with the redesigned track lighting. The dimming panel was resized for the existing design.

Branch Circuit Redesign

Please refer to the proceeding panelboard and power plan for additional information.

Dimmer Panel D2N1 Circuit 12

12 "K" fixtures * 62 input watts/fixture = 744 W

Total watts = 744W/ .9PF = 827VA

827VA/120V = 6.9A -> 2#12 Copper THWN

20A single pole breaker

¾" Conduit EMT

**Note: 20A*120V * 80% de-rating = 1,920 W Maximum allowed*

Voltage Drop Calculation

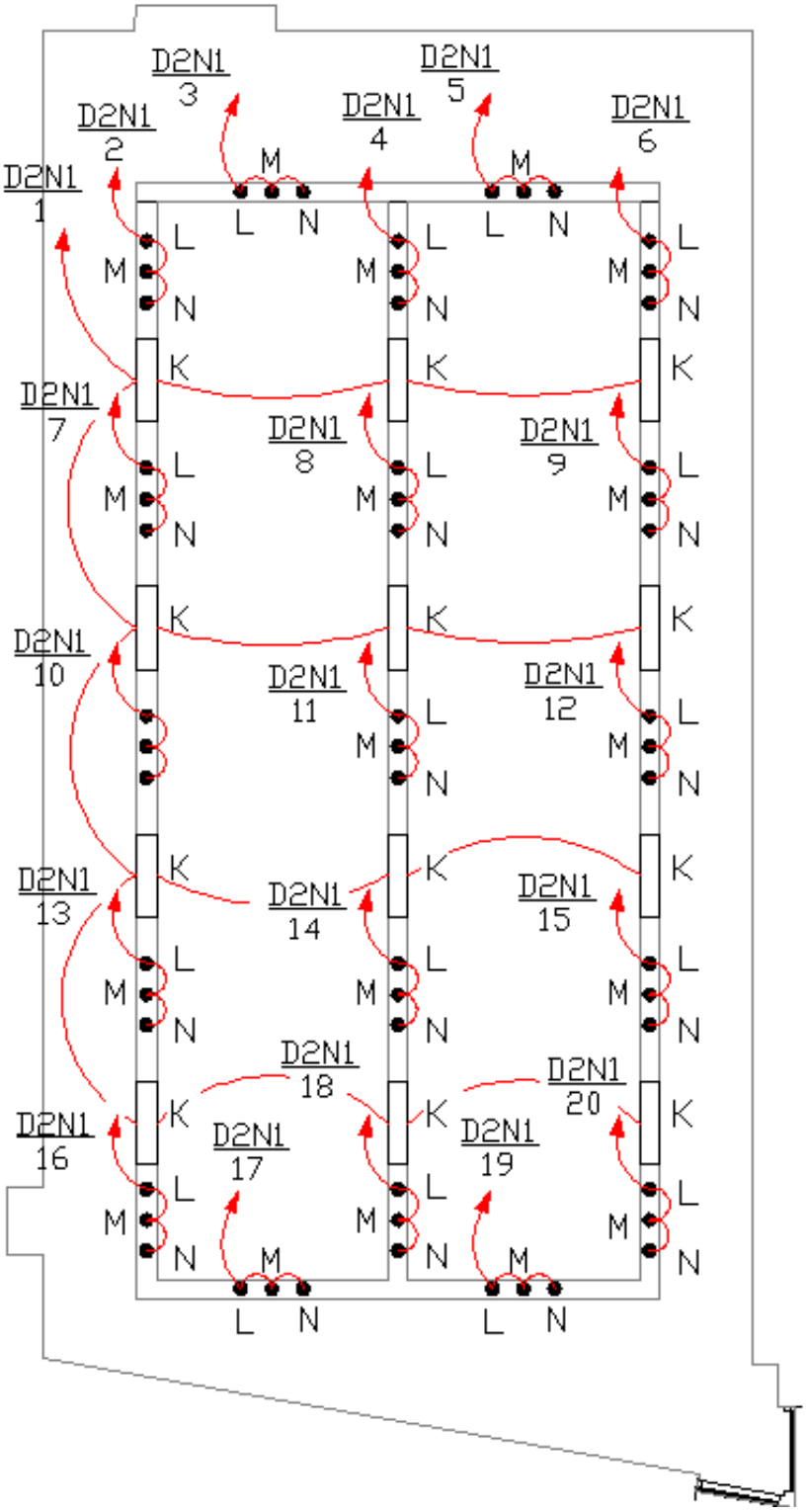
$V_{drop(l\text{-}n)} = A \bullet ft * V_{drop}/(1000\ A \bullet ft) * 2$(if single phase)

$\%V_{drop} = V_{drop(l\text{-}n)} / V$

Circuit Voltage	120
power factor	0.9
Length (ft)	75
Wire Size	#12
$V_{drop/(1000\ A\ ft)}$	1.749
Current (A)	6.9
1ϕ Multiplier	2
$V_{drop(l\text{-}n)}$	1.810
% V_{drop}	**1.509**

1.509% < 3% maximum per NEC recommendations

New Lighting Power Plan



** Note: See Appendix J for a 1/8" = 1'-0" Plan*

Existing R2NF Panelboard

PANELBOARD: R2NF		BUS RATING:							225 A		MAIN OCP		
MIN AIC:		VOLTAGE:							208 120 V		PHASE(S):		3
NEMA 1 ENCLOSURE		MOUNTING:							SURFACE		WIRES:		5
LOCATION:		NOTES:							200% NEUTRAL				
				LOAD, VA									
CH CIRCUIT DESIGN	P	TRIP	CKT	ϕA		ϕB		ϕC		CKT#	TRIP	P	CH CIRCUIT DESIGNATION
Recept - RM 1001	1	20	1	720	840					2	20	1	Recept - RM 1003
Recept - RM 1001	1	20	3			720	720			4	20	1	Recept - WC
Recept - RM 1001	1	20	5					720	300	6	20	1	Recept - RM 1002
Recept - RM 1001	1	20	7	720	900					8	20	1	Recept - RM 1002
Recept - RM 1001	1	20	9			720	1000			10	20	1	Recept - RM 1002
Recept - RM 1001	1	20	11					720	300	12	20	1	Recept - RM 1002
Recept - RM 1001	1	20	13	720	1000					14	20	1	Recept - RM 1002
Recept - RM 1001	1	20	15			720	528			16	20	1	CUH -6
Recept - RM 1001	1	20	17					720	864	18	20	1	CUH-1
Recept - Exterior	1	20	19	180						20	20	1	
Power Door	1	20	21			384				22	20	1	
Power Door	1	20	23					384		24	20	1	
Recept - Exterior	1	20	25	180						26	20	1	
	1	20	27							28	20	1	
	1	20	29							30	20	1	
	1	20	31							32	20	1	
	1	20	33							34	20	1	
	1	20	35							36	20	1	
			37							38			
PNL D2N1	3	60	39							40	60	3	PNL D2N2
			41							42			
PHASE CONNECTED LOAD, VA				5260		4792		4008					
PHASE BALANCE				12.23%		2.25%		-14.48%					

TOTAL CONNECTED L	14060
FUTURE GROWTH - 25	3515
TOTAL + FUTURE LOA	17575
TOTAL CURRENT, A	49
DESIGN CURRENT, A	61
MINIMUM MAIN OCP	150

Existing D2N1 Dimmer Panel

PANELBOARD: D2N1		BUS RATING:						60 A		MAIN OCP OR MLO: MLO			
MIN AIC:		VOLTAGE:						208 120 V		PHASE(S):			3
NEMA 1 ENCLOSURE		MOUNTING:						SURFACE		WIRES:			5
LOCATION:		NOTES:											
				LOAD, VA									
RANCH CIRCUIT DESIGNATIO	P	TRIP	CKT	ϕA		ϕB		ϕC		CKT#	TRIP	P	NCH CIRCUIT DESIGNATION
LTG - RM 1001	1	20	1	640	640					2	20	1	LTG - RM 1001
LTG - RM 1001	1	20	3			640	640			4	20	1	LTG - RM 1001
LTG - RM 1001	1	20	5					640	640	6	20	1	LTG - RM 1001
LTG - RM 1001	1	20	7	640	640					8	20	1	LTG - RM 1001
LTG - RM 1001	1	20	9			640	640			10	20	1	LTG - RM 1001
LTG - RM 1001	1	20	11					640	640	12	20	1	LTG - RM 1001
LTG - RM 1001	1	20	13	640	640					14	20	1	LTG - RM 1001
LTG - RM 1001	1	20	15			640	640			16	20	1	LTG - RM 1001
LTG - RM 1001	1	20	17					640	640	18	20	1	LTG - RM 1001
LTG - RM 1001	1	20	19	640	640					20	20	1	LTG - RM 1001
LTG - RM 1001	1	20	21			640	640			22	20	1	LTG - RM 1001
LTG - RM 1001	1	20	23					640	640	24	20	1	LTG - RM 1001
PHASE CONNECTED LOAD, VA				5120		5120		5120					
PHASE BALANCE				0.00%		0.00%		0.00%					

TOTAL CONNECTED LOAD, VA	15360
FUTURE GROWTH - 10%	1536
TOTAL + FUTURE LOAD, VA	16896
TOTAL CURRENT, A	47
DESIGN CURRENT, A	59
MINIMUM MAIN OCP	60

Redesigned R2NF Panelboard

PANELBOARD: R2NF		BUS RATING:						225 A		MAIN OCP			
MIN AIC:		VOLTAGE:						208 120 V		PHASE(S):		3	
NEMA 1 ENCLOSURE		MOUNTING:						SURFACE		WIRES:		5	
LOCATION:		NOTES:						200% NEUTRAL					
				LOAD, VA									
CH CIRCUIT DESIGN	P	TRIP	CKT	ϕA		ϕB		ϕC		CKT#	TRIP	P	CH CIRCUIT DESIGNATION
Recept - RM 1001	1	20	1	720	840					2	20	1	Recept - RM 1003
Recept - RM 1001	1	20	3			720	720			4	20	1	Recept - WC
Recept - RM 1001	1	20	5					720	300	6	20	1	Recept - RM 1002
Recept - RM 1001	1	20	7	720	900					8	20	1	Recept - RM 1002
Recept - RM 1001	1	20	9			720	1000			10	20	1	Recept - RM 1002
Recept - RM 1001	1	20	11					720	300	12	20	1	Recept - RM 1002
Recept - RM 1001	1	20	13	720	1000					14	20	1	Recept - RM 1002
Recept - RM 1001	1	20	15			720	528			16	20	1	CUH -6
Recept - RM 1001	1	20	17					720	864	18	20	1	CUH-1
Recept - Exterior	1	20	19	180						20	20	1	
Power Door	1	20	21			384				22	20	1	
Power Door	1	20	23					384		24	20	1	
Recept - Exterior	1	20	25	180						26	20	1	
	1	20	27							28	20	1	
	1	20	29							30	20	1	
	1	20	31							32	20	1	
	1	20	33							34	20	1	
	1	20	35							36	20	1	
			37	2344						38			
PNL D2N1	3	40	39			2344				40	60	3	PNL D2N2
			41					2344		42			
PHASE CONNECTED LOAD, VA				7604		7136		6352					
PHASE BALANCE				8.15%		1.50%		-9.65%					

TOTAL CONNECTED L	21093
FUTURE GROWTH - 25	5273
TOTAL + FUTURE LOA	26366
TOTAL CURRENT, A	73
DESIGN CURRENT, A	91
MINIMUM MAIN OCP	150

Main Overcurrent Protection

300A breaker

New Feeder Size

(3) #350 MCM and (1) #4 in 2 1/2" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. THWN Copper wire rated for 75°C.

Redesigned D2N1 Dimmer Panel

PANELBOARD: D2N1		BUS RATING:						60 A		MAIN OCP 40A				
MIN AIC:		VOLTAGE:						208 120 V		PHASE(S):		3		
NEMA 1 ENCLOSURE		MOUNTING:						SURFACE		WIRES:		5		
LOCATION:		NOTES:												
				LOAD, VA										
RANCH CIRCUIT DESIGNATIO	P	TRIP	CKT	ϕA		ϕB		ϕC		CKT#	TRIP	P	NCH CIRCUIT DESIGNATION	
LTG - RM 1001	1	20	1	827	450					2	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	3			450	450			4	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	5					450	450	6	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	7	450	450					8	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	9			450	450			10	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	11					450	450	12	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	13	450	450					14	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	15			450	450			16	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	17					450	450	18	20	1	LTG - RM 1001	
LTG - RM 1001	1	20	19	450	450					20	20	1	LTG - RM 1001	
Space	1	20	21							22	20	1	Space	
Space	1	20	23							24	-	1	Space	
PHASE CONNECTED LOAD, VA					3977		2700		2700					
PHASE BALANCE					27.24%		-13.62%		-13.62%					
TOTAL CONNECTED LOAD, VA		9377												
FUTURE GROWTH - 10%		938												
TOTAL + FUTURE LOAD, VA		10315												
TOTAL CURRENT, A		29												
DESIGN CURRENT, A		36												
MINIMUM MAIN OCP		40												

Main Overcurrent Protection

40A breaker

New Feeder Size

(3) #8 and (1) #10 in 3/4" Conduit

Based per NEC 2005. Tables 310-16, Table C.2, Table 250.122. THWN Copper wire rated for 75°C.

Energy Efficient Transformer Study

The Art & Visual Technology building utilizes 12 transformers throughout the building to supply electricity at either 480/277V or 208/120V power. The following study compares the use of energy efficient transformers versus standard ones.

The cost of the standard transformers was estimated from 2008 RS Means. Additionally, the cost of Powersmith's transformers was estimated to cost an additional 35%. The utility rate of $0.00272/kWh was used per the utility rate schedule of the building (GS-3 Dominion Virginia Power). This value seems extremely low to me, however I called to verify this information and a representative from Dominion Virginia assured me that all the information provided on their utility rate schedules is accurate. A typical 9 month, 12 hour operating schedule was used to estimate the building electrical usage.

**Note: A copy of the utility rate can be found in appendix D*

POWERSMITHS

The ESP Calculator™

Toll Free : 1-800-747-9627 or (905) 791-1493

Energy Savings Payback Calculator

Project Description	**Art & Visual Technology Building**			
Date	**1-Mar-07**			
	Transformers on Project		Standard Xfmr Co	PowerSmith Co
	QTY	**kVA**		
	2	15	$6,530	$8,816
	2	30	$4,385	$5,920
		45	$5,110	$6,899
	5	75	$7,000	$9,450
	3	112.5	$13,439	$18,143
		150	Total Cost	Total Cost
		225	$97,147	$131,148
		300		
		500		
		750		
		1000		
		1500		
		2000		
		7.5		
Available Full Load kW	**802.5**			
Average kVA (calc)	**67**			
equipment operating hrs/ day	12			
equipment operating days/yr	270	Calc Load kW	Calc Annual kWh	
Load during normal operating hours	40%	321	1,040,040	
Load outside operating hours	15%	120	664,470	
		Total Annual Load	**1,704,510**	
Annual Cost to Operate Load Only				
kWh rate	$ 0.003	Annual Consumption:	$ 4,636	
demand rate ($/kW/mo) ex. $10.00	$12.15	Annual Demand:	$ 46,802	
		Total Cost to run load	**$ 51,438**	

Annual Cost of Status Quo Transformer Losses & Associated Air Conditioning (A/C) burden

Status quo Efficiency (Normal Operation)	97.0%	
Transformer kW Losses (Normal Operation)	9.9	kW
Status quo Efficiency (Outside op. hrs)	92.0%	
Transformer kW Losses (Outside op. hrs)	10.5	kW
Annual addititional kWh from transformers	89,946	kWh
Annual Cost of Transformer Losses	$ 1,692	
A/C System Performance (kW/ton)	1.25	
Additional Tons of Cooling (on peak)	2.82	tons
Annual addititional kWh from A/C	31,941	kWh
Annual Cost of Associated A/C	$ 601	
Summary with Status Quo Transformer		
Annual Cost of feeding Building Load	$ 51,438	
Annual Cost of Transformer Losses	$ 1,692	
Annual Cost of Associated A/C	$ 601	
Electrical Bill (Status Quo Transformer)	**$ 53,731**	

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  doc#807-000440-110-AC 1-Mar-07

POWERSMITHS

Page 2

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Energy Savings Payback Calculator

Using Powersmiths instead of status quo transformers

Powersmiths Efficiency (Normal Operation)	98.2%	
Powersmiths kW Losses (Normal Operation)	5.9	kW
Powersmiths Efficiency (Outside op. hrs)	97.6%	
Transformer kW Losses (Outside op. hrs)	3.0	kW
Annual addititional kWh from transformers	35,403	kWh
Annual Cost of Powersmiths Losses	$ 954	
Additional Tons of Cooling (on peak)	1.67	tons
Annual addititional kWh from A/C	12,572	kWh
Annual Cost of Associated A/C	$ 339	

Comparing Status Quo & Powersmiths

	Status Quo	Powersmiths	
Annual Cost of feeding Building Load	$ 51,438	$ 51,438	
Annual Cost of Transformer Losses	$ 1,692	$ 954	
Annual Cost of Associated A/C	$ 601	$ 339	**Reduction**
Annual estimated Electrical Bill	$ 53,731	$ 52,731	**2%**

Peak kW reduction (normal op hours)	**4.0**	**kW**
Annual kWh reduction	**73,912**	**kWh**
Reduction in Air Conditioning Load (on peak)	**1.15**	**tons**

Cost Analysis (calc)

Energy Cost Escalation (above inflation)	3.0%
Annual Power Quality Benefit	$ -

	Annual Operating Cos	Life Cycle Operating Cost & Savings 20 years	32 years
Status Quo Transformers	$2,293	$82,829	$188,952
Powersmiths Transformers	$1,293	$46,706	$106,547
Savings with Powersmiths	**$1,000**	**$36,123**	**$82,404**

Cost	**Cost**
Powersmiths Transformers	$131,148
Status Quo Transformers	$97,147

Payback on total cost	34.00	years	current kWh rate:
Cost of Energy Savings	$ 0.014	/kWh	$0.003
Cost - Benefit Ratio	0.2	times less to save a kWh than to buy a kWh	

Leasing Option	60 Month Term	48 Month Term	36 Month Term
Total Annual Leasing Payments	**$24,563**	**$29,960**	**$38,120**
Net Annual Cost with savings	$23,563	$28,960	$37,120

Summary of Environmental Benefits

Annual Reduction in Greenhouse Gases (per EPA)		Equivalence	
55	tons of CO2	10	Acres trees plan
177	tons of Coal	7	Car Emissions
428	kgs of SO2	7	homes heated
184	kgs of NOx		

IMPORTANT: By using the ESP Calculator™, you are agreeing the TERMS OF USE section on pa
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POWERSMITHS

Conclusion

Based on Powersmith's ESP calculator, energy efficient transformers will save roughly $1,000 a year. With the initial increased cost of nearly $35,000, it will take about 34 years for the energy efficient transformers to pay themselves back. Over the life span of the system (32 years) energy efficient transformers will save roughly $82,000 in energy savings. In addition to the financial savings, the reduced energy usage equates to roughly 10 acres of trees planted each year. In this instance, due to the extremely low utility rate, I would not recommend the use of energy efficient transformers. However, in other instances where the utility rate is a more typical range $0.10/kWh energy efficient transformers can be very beneficial.

Photovoltaic Array Study

A relatively attractive climate along with federal and state incentives makes the possibility of a photovoltaic array to be financial feasible for the Art & Visual Technology Building. The following study investigates the use of a photovoltaic array on roof of the Art & Visual Technology building. This study was conducted with the aid of RestScreen® to determine if the proposed system of 170 watt monocyrstalline (product number BP 5170) photovoltaic modules produced by BP Solar would be beneficial to implement. The aim of this study was to compare the cost of the solar panels versus the cost savings of energy production. Therefore, the cost of engineering, feasibility studies, and balancing were not included.

**See appendix E for the product cut sheet*

The federal and state incentives for the installation of a photovoltaic are integral to the financial success of installing such a system. These incentives help offset the high initial cost of purchasing and installing the system. After research of available state incentives for the production of renewable energy, it was found that no state incentives were applicable for this application. Many federal incentives are available but, are based on federal tax rebates. Since GMU is a university, most of these incentives were not applicable. The only incentive obtainable for this project was:

Federal Renewable Energy Production Incentive (REPI)

Introduced in the Energy Policy Act of 1992, the federal government provides financial assistance to energy producing facilities at the rate of 1.5 cents per kilowatt hour (1993 dollars, indexed for inflation) for the first ten years of operation. As estimated by www.moneytimes.com, the average inflation rate over this period was 2.69%, which equates to a rate of 2.22 cents per kilowatt hour.

Design Parameters

To find the potential photovoltaic system size an approximation of available roof square footage was determined. 80% of the available roof area was assumed to be useable for installation of photovoltaic modules.

Available space on roof = 9,775 ft^2

Usable space on roof = 7,820 ft^2

Module Size (31"x 62.7") = 13.5 ft^2

Module Nominal Power = .170kW

Number of Modules = 7,820 ft^2/ 13.5 ft^2 = 579

Maximum Nominal Power = **98.4kW**

Weather data for Fairfax, Virginia was not obtainable, however weather data for Washington D.C. was used as it is close in proximity to Fairfax. The avoided cost of energy was $0.272 which was determined from the utility rate for the campus.

Estimated Initial Cost

Module Cost 98.4kW * $5,750/kW = $565,800

Estimated intermittent Cost

Periodic Inverter Replacement* = $50,000

Misc. Cost** = $28,700

Annual Operating & Maintenance = $880

**Note: Per RetScreen recommendations*

***Note: Includes Training & 5% Contingency*

Federal Renewable Energy Production Incentive (REPI)

Savings $0.0222/kWh for the first ten years

RetScreen Results

RETScreen® Energy Model - Photovoltaic Project

Training Calendar

Site Conditions		Estimate	Notes/Range
Project name		Art & Visual Technology	See Online Manual
Project location		Fairfax, VA	
Nearest location for weather data	-	Washington, DC	Complete SR&SL sheet
Latitude of project location	°N	38.9	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.52	
Annual average temperature	°C	14.5	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	On-grid	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		BP Solar/ BP 5170 S	See Product Database
Nominal PV module efficiency	%	13.5%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	**98.40**	
PV array area	m²	728.9	
Power Conditioning			
Average inverter efficiency	%	90%	80% to 95%
Suggested inverter (DC to AC) capacity	kW (AC)	88.6	
Inverter capacity	kW (AC)	72.0	
Miscellaneous power conditioning losses	%	0%	0% to 10%

Annual Energy Production (9.19 months analysed)		Estimate	Notes/Range
Specific yield	kWh/m²	126.2	
Overall PV system efficiency	%	11.2%	
PV system capacity factor	%	10.7%	
Renewable energy collected	MWh	102.181	
Renewable energy delivered	MWh	**91.963**	
	kWh	91,963	
Excess RE available	MWh	**0.000**	
			Complete Cost Analysis sheet

RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Washington, DC	See Weather Database
Latitude of project location	°N	38.9	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30.0	0.0 to 90.0
Azimuth of PV array	°	0.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	0.60	1.81	1.4	2.61	-
February	1.00	2.57	3.1	3.34	-
March	1.00	3.55	8.4	4.08	-
April	1.00	4.60	13.6	4.79	-
May	1.00	5.42	19.1	5.23	-
June	0.33	5.99	24.2	5.58	-
July	0.33	5.73	26.7	5.42	-
August	0.33	5.10	25.8	5.14	-
September	1.00	4.23	21.8	4.71	-
October	1.00	3.16	15.4	3.97	-
November	1.00	2.05	9.9	2.91	-
December	0.60	1.52	4.1	2.22	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.39	1.01
Solar radiation (tilted surface)	MWh/m²	1.52	1.13
Average temperature	°C	14.5	13.0

Load Characteristics		Estimate
Application type	-	On-grid

Return to Energy Model sheet

RETScreen® Financial Summary - Photovoltaic Project

Annual Energy Balance

Project name		Art & Visual Technology			
Project location		Fairfax, VA	Nominal PV array power	kWp	100.00
Renewable energy delivered	MWh	93.458			
Firm RE capacity	kW	-			
Application type		On-grid			

Financial Parameters

Avoided cost of energy	$/kWh	0.003	Debt ratio	%	0.0%
RE production credit	$/kWh	0.015			
RE production credit duration	yr	20			
RE credit escalation rate	%	2.0%			
			Income tax analysis?	yes/no	No
Energy cost escalation rate	%	5.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	25			

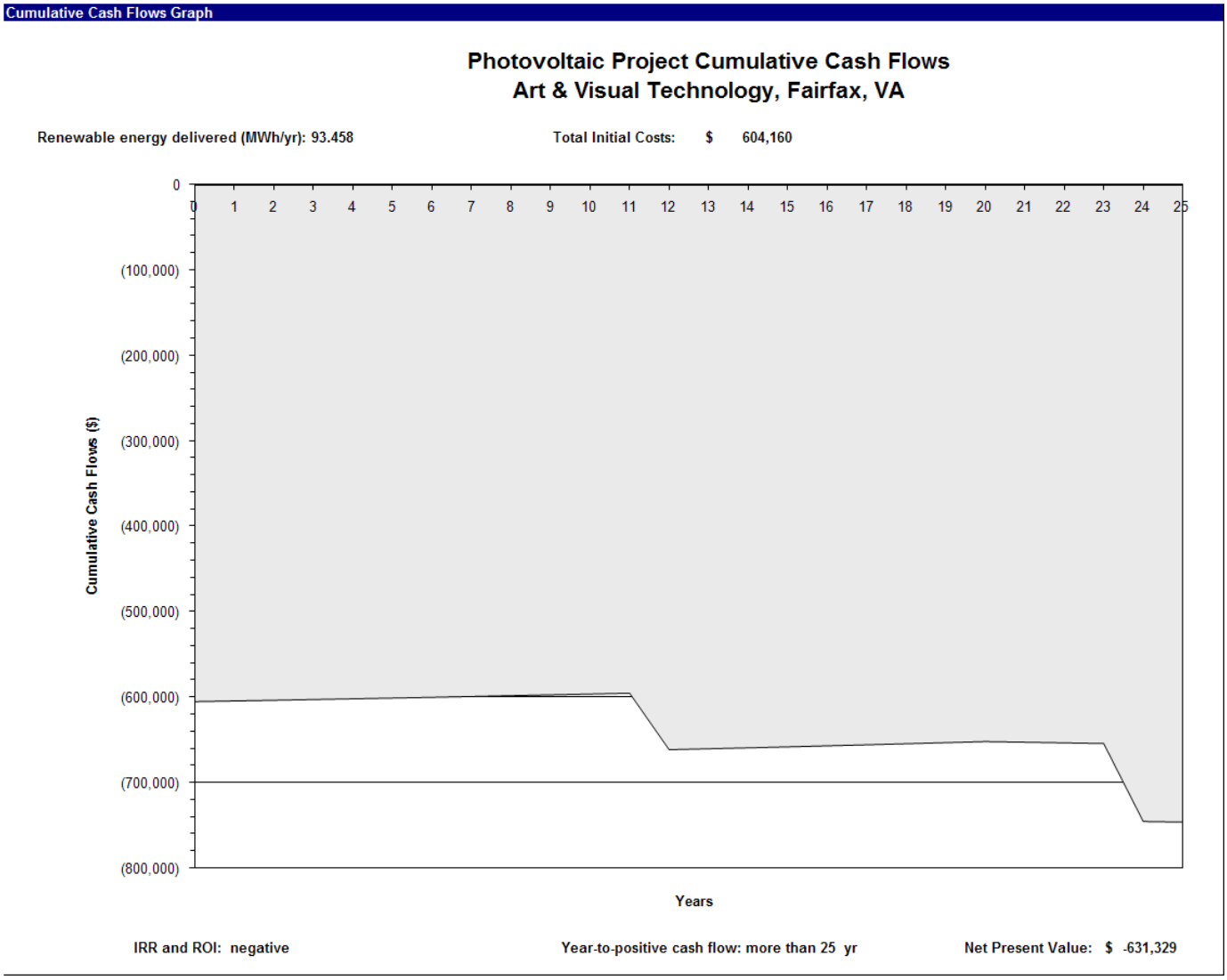
Project Costs and Savings

Initial Costs				Annual Costs and Debt		
Feasibility study	0.0%	$	-	O&M	$	880
Development	0.0%	$	-	Fuel	$	-
Engineering	0.0%	$	-			
Energy equipment	95.2%	$	575,000	**Annual Costs and Debt - Total**	**$**	**880**
Balance of equipment	0.0%	$	-			
Miscellaneous	4.8%	$	29,160	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**$**	**604,160**	Energy savings/income	$	254
Incentives/Grants		$	-	RE production credit income - 20 yrs	$	1,402
				Annual Savings - Total	**$**	**1,656**
Periodic Costs (Credits)						
Inverter Repair/Replacement		$	50,000	Schedule yr # 12,24		
		$	-			
		$	-			
End of project life -		$	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	negative	Energy production cost	$/kWh	0.43
After-tax IRR and ROI	%	negative			
Simple Payback	yr	778.5			
Year-to-positive cash flow	yr	more than 25	Project equity	$	604,160
Net Present Value - NPV	$	(631,329)			
Annual Life Cycle Savings	$	(64,273)			
Benefit-Cost (B-C) ratio	-	(0.04)			

Version 3.2



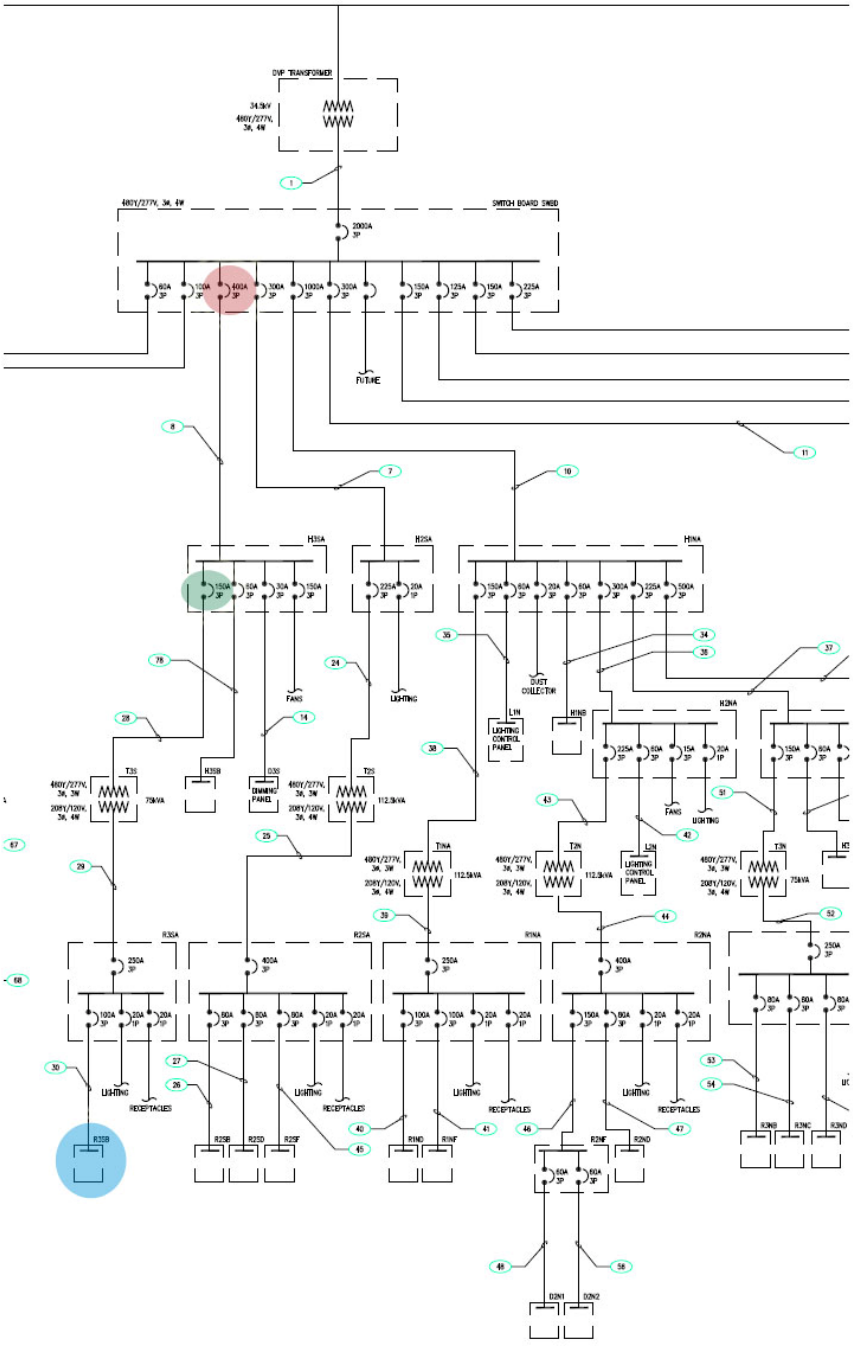
Photovoltaic Array Conclusion

The designed photovoltaic system yielded a twenty-five year plus payback period for the owner. The net energy production cost came out to be roughly $0.43/kWh which is much higher than the utilities' rate of $0.00272/kWh. As discussed earlier in this report, I believe that the utility rate is extremely low. This is what drove the payback period to be at least 25 years. I had tested the same setup with using a rate of $0.10/kWh and got an output of roughly 15 years for the payback period. Since the federal incentive packages are based on federal tax savings and the avoided cost of energy (utility rate), implementing photovoltaic array on the Art & Visual Technology building is not

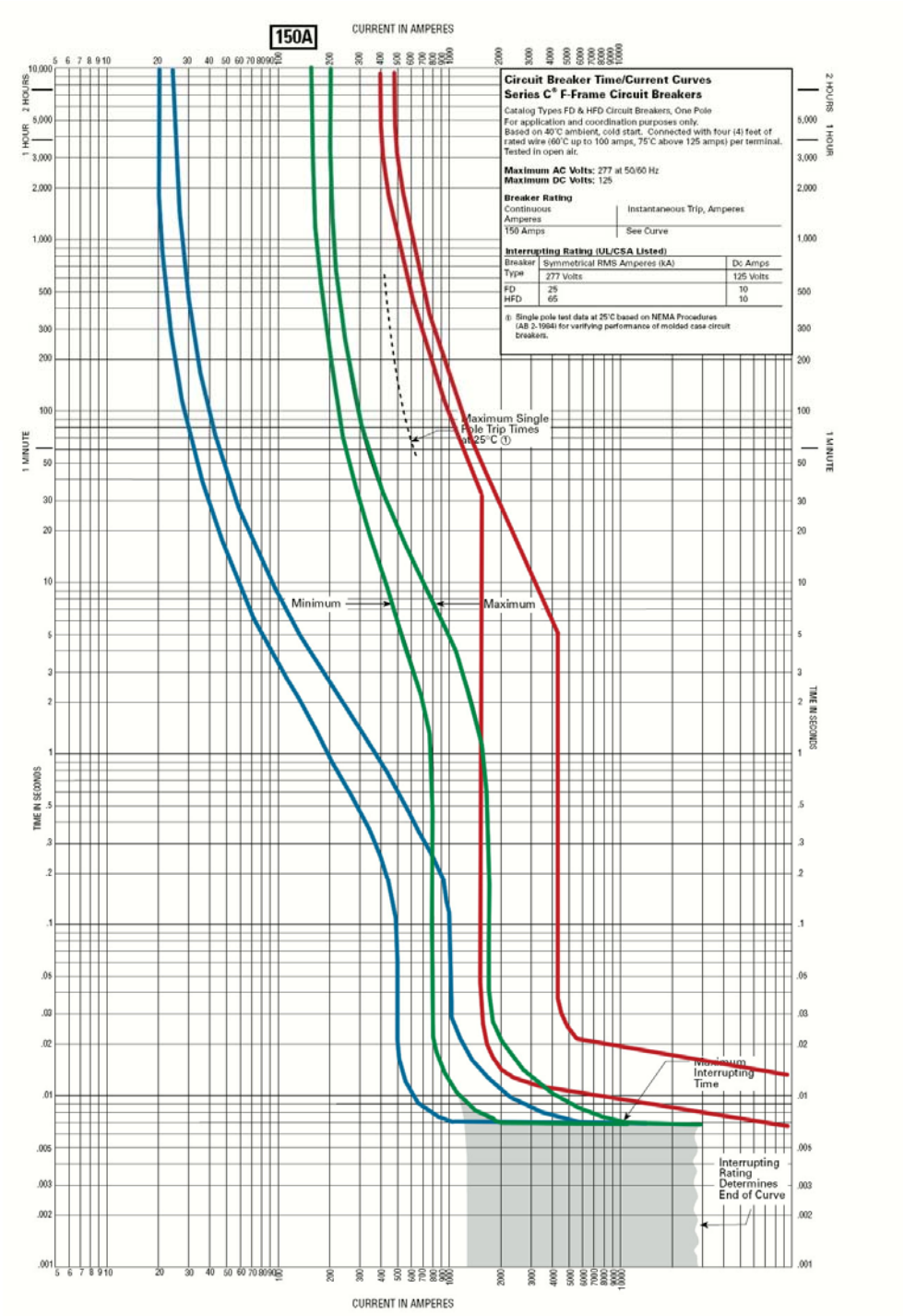
recommended. However, on a project whose owner pays federal taxes and a higher utility rate, a photovoltaic array could be highly recommended.

Over Current Protection Coordination Study

The following coordination study examines the trip time curves for the three breakers shown on the proceeding schematic. A 400A 3 pole breaker on the main switch gear, a 150 A 3 pole breaker on a distribution panel and a typical 20A single pole branch circuit breaker were selected for the analysis.



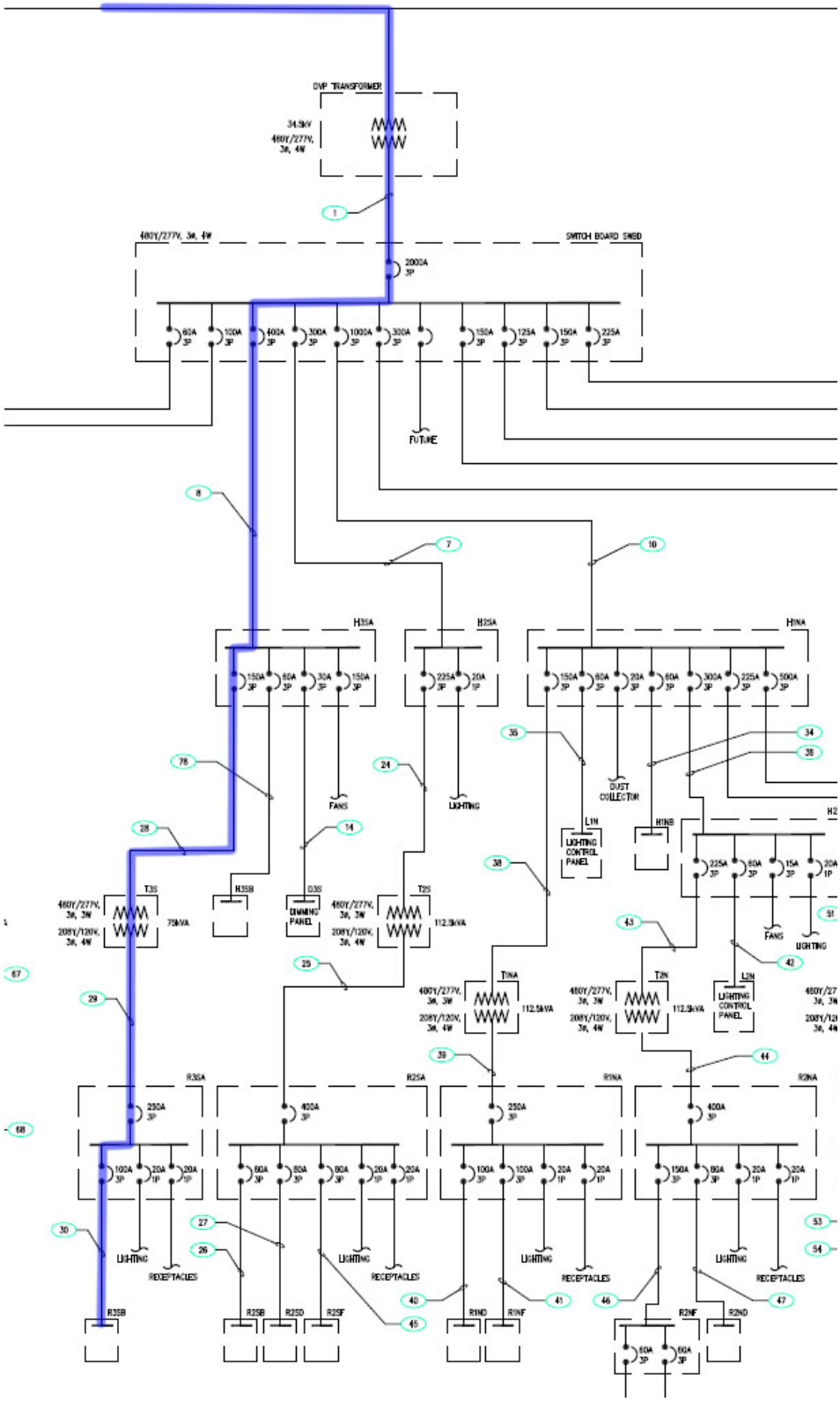
20A Branch Circuit Breaker 150A 3 Phase Circuit Breaker 400A 3 Phase Circuit Breaker



Evaluation

Upon laying the current trip curves over each other, it was found that the coordination of the chosen path was properly coordinated with the breaker furthest downstream tripping first and each consecutive breaker up stream breaking next.

Short Circuit Analysis



I was unable to contact Dominion Virginia Power, therefore with the recommendations of Professor Dannerth, the Utility transformer size was estimated at 750kVA. The following is the summary table of the short circuit analysis at each point throughout the system. The calculations used to tabulate the summary are in the following section.

Point	Location	Available Fault	Standard Breaking Rating
A	Utility Transformer Secondary	17,803	25,000
B	SWBD	16,243	25,000
C	Panel H3SA	14,790	25,000
D	T3S	14,408	25,000
E	R3SA	1,425	14,000
F	R3SB	1,400	14,000

Per Unit Method				
BASE kVA	1000			
Utility Company Available Fault	1000000			
System Voltage (kV)	0.48			
Utility Transformer Primary				
Utility Transformer Size	750		X (p.u.)	0.001
Utility Transformer Secondary				
Average % Z.	5		X (p.u.)= (%X * base kVA/ 100 *xfmr kVA)	0.059507777
Average X/R	1.98		R(p.u.) = (%R * base KVA/ 100 *xfrmr kVA)	0.030054433
X (%)	4.463			
R (%)	2.254		ΣX(p.u.)	0.060507777
			ΣR(p.u.)	0.030054433
			ΣZ(p.u.)	0.067560787
			$I_{sc\ rms\ sym}$	17803.4198
Main SwitchBoard				
# of sets	6		X(p.u.)	0.00531684
length	150		R(p.u.)	0.003862847
Wire Size	400kcmil			
X_L	0.049		ΣX(p.u.)	0.065824617
R	0.0356		ΣR(p.u.)	0.03391728
X	0.001225		ΣZ(p.u.)	0.074049052
R	0.00089		$I_{sc\ rms\ sym}$	16243.46331
Panel H3SA				
# of sets	1		X(p.u.)	0.008038194
length	40		R(p.u.)	0.000111545
Wire Size	600kcmil			
X_L	0.0463		ΣX(p.u.)	0.073862812
R	0.0257		ΣR(p.u.)	0.034028825
X	0.001852		ΣZ(p.u.)	0.08132451
R	2.57E-05		$I_{sc\ rms\ sym}$	14790.28972
Transformer T3S				
# of sets	1		X(p.u.)	0.00234375
length	10		R(p.u.)	5.55556E-05
Wire Size	#1/0			
X_L	0.054		ΣX(p.u.)	0.076206562
R	0.0128		ΣR(p.u.)	0.034084381
X	0.00054		ΣZ(p.u.)	0.083481645
R	1.28E-05		$I_{sc\ rms\ sym}$	14408.11404

Secondary T3S				
Transformer Size	75		X (p.u.)= (%X * base kVA/ 100 *xfmr kVA)	0.615409881
Average % Z.	5.7		R(p.u.) = (%R * base KVA/ 100 *xfrmr kVA)	0.445949189
Average X/R	1.38			
X (%)	4.616		ΣX(p.u.)	0.691616442
R (%)	3.345		ΣR(p.u.)	0.480033569
			ΣZ(p.u.)	0.841882136
			$I_{sc\ rms\ sym}$	1428.719068
Panel R3SA				
# of sets	1		X(p.u.)	0.002148438
length	10		R(p.u.)	0.000239583
Wire Size	250kcmil			
X_L	0.0495		ΣX(p.u.)	0.69376488
R	0.0552		ΣR(p.u.)	0.480273153
X	0.000495		ΣZ(p.u.)	0.843784338
R	5.52E-05		$I_{sc\ rms\ sym}$	1425.498206
Panel R3SB				
# of sets	1		X(p.u.)	0.018554688
length	75		R(p.u.)	6.94444E-05
Wire Size	#1			
X_L	0.057		ΣX(p.u.)	0.712319567
R	0.016		ΣR(p.u.)	0.480342597
X	0.004275		ΣZ(p.u.)	0.859143863
R	0.000016		$I_{sc\ rms\ sym}$	1400.013564