Electrical Depth

Depth Overview

The purpose of my electrical depth is to explore the existing 208/120 V distribution system. The existing design for Duques Hall is more than sufficient to provide adequate service through out the building. This breadth examines two different ways to distribute the 208/120 V throughout the building. Each design of the system includes a calculation of the loads on the panel, and the design of the circuit breaker and wire feeder supplying the panel. After loading the panels, the system design included determining the sizing involved with the distribution of the system, including the proper sizing of the distribution systems (transformers and switchgear). Only the 208/120 V systems were examined in the redesign of the power distribution systems. The 480/277 V system and the emergency power systems were not touched, and remain as they were originally designed.

The primary goal of the breadth design is to provide two contrasting systems capable of distributing proper power throughout the building. A secondary consideration in the design is to ensure that the two designs perform in the most effective manner possible.

Existing System Narrative –

The electrical power for Duques Hall, the new George Washington School of Business and Public Management, is fed from an existing system. The utility is run onto the block and fed through 13200 feeders into an existing substation at Funger Hall, an existing substation at Tompkin Hall, and a new feed running to Duques Hall. The system can be described as a primary selective radial distribution system. Upon entering the building, the 15 kv feed is run into Switchgear HDP, which is then tapped into Switchgear CDP, which is then tapped into Switchgear NDP. Switchgear NDP steps the 15kv feed down for the 480/277 system which feeds mechanical equipment and most of the electrical lights for the building, and the other two Switchgears which step down to the 208/120 system feeds the building receptacles and the lighting which is fed by 208/120 volts. There are two switchgears supplying two separate 208/120 volt systems because one of the systems is an isolated ground system. Isolated ground systems provide additional grounding for receptacles running loads that typically contain computer systems. An Isolated ground system provides an extra ground wire to eliminate oscillations across frequencies that are typically caused by motor loads. Switchboard NDP provides power for the normal system and Switchboard CDP provides power to the isolated ground systems.

Riser I

The purpose of Riser one was to attempt to eliminate the cost of purchasing three separate switchgears. Switchgears are very expensive pieces of equipment, and if it was possible to eliminate two of the switchgears from the space, major cost savings could be realized. One of the major concerns; however, is if the switchgear will be able to handle the load scattered through the entire building.

Loading Panels

To begin the design of my systems, I recalculated the loads on the 208/120 V systems. The existing loads were taken from the existing panel boards which can be found in the attached CD**.**

Sizing the Panel boards was performed according to NEC 2002 Standards. Panelboard C1, A two section Panel serving the isolated ground loads on the first floor is shown below.

C1 section 1, Existing Kva - 57.4 KVA
C1 section 2, Existing Kva – 22 KVA

Receptacle loads sized with the first 10 KVA at 100 % of the existing load and the remaining load is sized at 50% existing load.

Design KVA → 57.4 KVA + 22 KVA = 79.4 KVA →
10 KVA + 69.4 KVA * .5 = 44.7 KVA

The KVA on the panel is converted to an ampacity value so the breaker may be sized.

44.7 KVA * 1000 / (208 V * sqrt(3)) = 124.1 Amps

Panels are sized up 25% of their value to allow for future expansion to the panel.

124.1 Amps * 1.25 = 155.1 Amps

The sized panel allows the panel frame and panel breaker to be sized. My panels were sized using the Square D catalog.

Frame Size = 225 A
Breaker trip Size = 175 A

Wire Sizing was sized using the amperage on the breaker and referring to table 310.16 of the NEC 2002. The wire was sized assuming THHW wire at a 75^{o} C rating. An isolated ground system has 5 main wires.

Wire Size = (4) 2/0 AWG Wire

Grounding was sized using Table 250.122 in the NEC 2002. Isolated Ground systems have two grounding wires.

Grounding Wire Size = (2) #4 AWG Wire

Conduit is sized according to Appendix C of the NEC. When Sizing the wire, it was assumed that the ground wire was the same size as the normal wires. For this situation, it was assumed there were (6) wires at 2/0 AWG.

Conduit Size = 2”

The remainder of the isolated ground panels were sized in the same manner, and are provided in the following table.

Isolated Ground Panels 208/120									
Panel	Existing KVA	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
C1 - sect1	57.4	44.7	124.1	155.1	225 A	175 A	(5) 2/0 AWG	(2) #4	2 - 1/2"
C1 - sect2	22								
C1B	30.2	20.1	55.8	69.7	100 A	70 A	(5) 4 AWG	(2) #8	1 - 1/2"
C2 - sect 1	58.6	52.9	146.7	183.4	225 A	200 A	(5) 3/0 AWG	(2) #4	2 - 1/2"
C2 - sect 2	37.1								
C2B	32.2	21.1	58.6	73.2	100 A	80 A	(5) 4 AWG	(2) #8	1 - 1/2"
C3 - sect 1	66	58.3	161.8	202.3	225 A	225 A	(5) 4/0 AWG	(2) #2	3"
C3 - sect 2	40.6								
C3B	40.4	25.2	69.9	87.4	100 A	90 A	(5) 3 AWG	(2) #8	1 - 1/2"
C4	47.7	28.9	80.1	100.1	225 A	125 A	(5) 1 AWG	(2) #6	2"
C4B	17.6	13.8	38.3	47.9	100 A	50 A	(5) 8 AWG	(2) #8	1 - 1/4"
C5	50.5	30.3	84.0	105.0	225 A	125 A	(5) 1 AWG	(2) #6	2"
C5B	10.9	10.5	29.0	36.3	100 A	40 A	(5) 8 AWG	(2) #8	1 - 1/4"
C6	71.3	40.7	112.8	141.0	225 A	150 A	(5) 1/0 AWG	(2) #6	2"
C6B	36.6	23.3	64.7	80.8	100 A	90 A	(5) 3 AWG	(2) #8	1 - 1/2"

The Panels that are marked in yellow are main circuit breaker panels. These panels will provide power to the floors above and below them. To provide the proper load to these panels, the MCB panels must be sized to handle their load and the load on all the panels that they distribute power to. They are sized the same way as a normal panel.

C2 KVA = C2 + C1 + C3 + C1B + C2B + C3B
C2 KVA = 384.5
Sized KVA = 384.5 * 1.25 = 684.4
Panel Frame = 800 A
Panel Breaker = 800 A

There is no wire size on the chart in the NEC that will accommodate such a large load. It is also very uncommon in design practice to use a wire size much larger than 400 MCM. In such a situation, the ampacity is best divided and distributed over numerous runs as was done in this case. The ampacity was assumed for three runs around 270 A. The wiring is sized below.

Wiring – 3 sets, 5 wire, 300 MCM
Ground – 2 wire, #2 AWG
Conduit Size – (3) 3”

The isolated main circuit breaker panels are sized as above, and contained in the table below.

MCB Isolated Wire Sizing

Panel	Breaker	Wire Size	Ground Size	Conduit Size
C2	800 A	* (5) 300 MCM	(2) #2	(3) 3"
C5	450 A	**(5) 4/0 AWG	(2) #1/0	(2) 3"

* Three sets of Wiring
** Two sets of Wiring

The calculations performed in this table are provided on a spreadsheet which can be found with the attached CD**.**

The power distribution to the non isolated panels and the loading of the panels was done in the same way. These panels also contained motor loads. The loads were divided and summed separately with the motor loads receiving a design factor of 1.0 and the receptacle loads being designed as the receptacles in the last section were designed. The loaded panels are included in the table below.

208/120 Panels											
Panel	Recepticle KVA	Motor Kva	Existing Kva	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
NP2	5.76	23.74	29.5	29.5	81.9	102.4	225 A	125 A	(4) 1 AWG	(1) #6	2"
N1	10.13	46.67	56.8	56.735	157.5	196.9	225 A	200 A	(4) 3/0 AWG	(1) #4	2 1/2"
N1B	1.58	8.62	10.2	10.2	28.3	35.4	100 A	40 A	(4) 8 AWG	(1) #8	1"
N2	7.92	15.58	23.5	23.5	65.2	81.5	100 A	90 A	(4) 3 AWG	(1) #8	1 - 1/4"
N2B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 8 AWG	(1) #8	1"
N3	12.4	6.7	19.1	17.9	49.7	62.1	100 A	70 A	(4) 4 AWG	(1) #8	1 - 1/4"
N3B	2.34	1.06	3.4	3.4	9.4	11.8	100 A	15 A	(4) 8 AWG	(1) #8	1"
N4	19.22	12.78	32	27.39	76.0	95.0	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N4B	5.04	2.56	7.6	7.6	21.1	26.4	100 A	30 A	(4) 8 AWG	(1) #8	1"
N5	11.7	16.1	27.8	26.95	74.8	93.5	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N5B	5.04	1.06	6.1	6.1	16.9	21.2	100 A	25 A	(4) 8 AWG	(1) #8	1"
N6	16.16	33.14	49.3	46.22	128.3	160.4	225 A	175 A	(4) 2/0 AWG	(1) #4	2"
N6B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 8 AWG	(1) #8	1"
NPH	1.8	3	4.8	4.8	13.3	16.7	100 A	20 A	(4) 8 AWG	(1) #8	1"

Panels NP2, N3 and N6 are all main circuit breakers so they had to be resized to provide for their loads and the loads of the panels they feed. The resized panels are listed in the table below.

MCB Wire Sizing				
Panel	Breaker	Wire Size	Ground Size	Conduit Size
NP2	350 A	** 2/0 AWG	(1) 4 Awg	(2) 2-1/2"
N3	300 A	** 1/0 AWG	(1) 6 AWG	(2) 2"
N6	300 A	** 1/0 AWG	(1) 6 AWG	(2) 2"

** Two sets of Wires

The calculations for the resizing of these panels is provided in the spreadsheet which can be found with the attached CD.

Sizing Transformers

The load is provided to the building at 13200 and stepped down in switchgear NDP to 480/277 volts. Switchgear NDP provides feeds through the building at 480/277 V. To enable the 208/120 V systems to work properly, the voltage must be stepped down through the transformers. In Riser 1, there are 5 separate transformers. Three transformers: NP2, N3, and N6, provide power to the non-isolated systems. The remaining two transformers, C2 and C5, provide power to the isolated ground systems.

The transformers are sized at a KVA value equivalent to the load they are serving. In this case my transformers were sized to accommodate the loads on my main circuit breakers. Once the transformers were sized, the wiring was sized based on the KVA load value and voltage on the primary side of the transformer.

Transformer 2 serves panel C2 at 197.3 KVA
T-2 is rated at 225 KVA

Ampacity = 225 * 1000 / (208 * sqrt(3)) = 469 Amps

Wire sized is based on the amperage provided by the transformer. Wires Leading up to a transformer do not have a ground wire or neutral wire, so conduit is only assumed for three wires. For transformer T-2, the amperage was two great to run a single conduit so the load was divided.

Wire Size = 2 sets, 3 wire, 250 MCM
Conduit size = (2) 2”

The sizing for the transformers were performed in the previous matter. All other transformers are sized in the following chart. All sizes were based off a Square D manufacturer’s catalog.

Transformer Schedule

Xfrmer	Serving Panel	KVA Load	Xfrmer Size	Ampacity	Wire Size	Conduit
T-P2	NP2	92.8	112.5	234.5	(3) 250 MCM	2"
T-2	C2	197.3	225	469.0	** (3) 250 MCM	(2) 2"
T-3	N3	74.31	75	156.3	(3) 2/0 AWG	1 - 1/2"
T-5	C5	122.3	150	312.6	** (3) 2/0 AWG	(2) 1 - 1/2"
T-6	N6	82.82	112.5	234.5	250 MCM	2"

** Two sets of Wires

The calculations for the transformer sizing can be found in the excel spreadsheet located with the attached CD.

Voltage Drop

Wire’s extended over long distances lose voltage the longer the run of wire travels. In Duques Hall, there are numerous sections where there are extended runs that have the potential of dropping unacceptable amounts. According to NEC standards, the voltage drop across the feeders must not exceed 2% and the voltage drop across the branch circuits must not exceed 3%. This provides that there is no voltage drop greater than 5% through the wire runs.

My calculations were performed so that the voltage drop from the transformer to the MCB plus the voltage drop from the MCB to the MLO panels will not exceed 5%. Each section was calculated starting with the longest run of wire, and no more calculations were performed once the wires no longer needed to be resized. Each wire size has a K value associated with it as a factor of voltage drop. These values were taken from table 11.5 in "Electrical Systems in Building" by S. David Hughes.

Voltage Drop = (K * A * (Length / # runs)) / 1000

% Voltage Drop = Voltage Drop / 120 V

Voltage Drop = (.11 * 350 * (15 / 2)) / 1000 = .29

% Voltage Drop = .29 / 120 = .2 %

Calculations of Voltage drop in my space is recorded in this table.

Voltage Drop for Long Runs

Run	Length	Number	Size	K	Ampacity	Volt drop	% Volt Drop	Base Drop
NP2 to T-P2	15	2	2/0 AWG	0.11	350	0.29	0.2%	-
NP2 to N1B	211	1	8 AWG	0.196	40	1.65	1.4%	1.6%
Np2 to N1	42	1	3/0 AWG	0.092	200	0.77	0.6%	2.0%
T-3 to N3	15	1	4/0 AWG	0.075	300	0.34	0.3%	-
N3 to N4B	170	1	8 AWG	0.699	30	3.56	3.0%	3.3%
N3 to N2B	185	1	8 AWG	0.699	40	5.17	4.3%	4.6%
N3 to N3B	170	1	8 AWG	0.699	15	1.78	1.5%	1.8%
T-6 to N6	15	3	2/0 AWG	0.11	300	0.17	0.1%	-
N6 to N5B	185	1	8 AWG	0.699	25	3.23	2.7%	2.8%
N6 to NPH	36	1	8 AWG	0.699	40	1.01	0.8%	1.0%
N6 to N6B	170	1	8 AWG	0.699	20	2.38	2.0%	2.1%
T-2 to C2	15	3	300 mcm	0.064	800	0.26	0.2%	-
C2 to C1B	185	1	4 AWG	0.3	70	3.89	3.2%	3.5%
C2 to C2B	170	1	4 AWG	0.3	80	4.08	3.4%	3.6%
C2 to C3B	185	1	3 AWG	0.3	90	5.00	4.2%	4.4%
T-5 to C5	15	2	4/0 AWG	0.075	450	0.25	0.2%	-
C5 to C4B	185	1	8 AWG	0.699	50	6.47	5.4%	5.6%
C5 to C5B	170	1	8 AWG	0.699	40	4.75	4.0%	4.2%
C5 to C6B	185	1	3 AWG	0.196	90	3.26	2.7%	2.9%

Using this table, which was built in excel, the wire sizes were adjusted to accommodate voltage drop. The K values were adjusted till the drop on each wire was under 2% for the feeder branch, and then the new K value was used to find the corresponding wire size. The new wire sizes are recorded on the following page, and the excel sheet used to calculate the voltage drop can be found with the attached CD.

Voltage Drop Resizing								
Run	**length**	**number**	**size**	**K**	**Ampacity**	**Volt drop**	**% Volt Drop**	**Base Drop**
NP2 to T-P2	15	2	2/0 AWG	0.11	350	0.29	0.2%	-
NP2 to N1B	211	1	8 AWG	0.196	40	1.65	1.4%	1.6%
Np2 to N1	42	1	3/0 AWG	0.092	200	0.77	0.6%	2.0%
T-3 to N3	15	1	4/0 AWG	0.075	300	0.34	0.3%	-
N3 to N4B	170	1	4 AWG	0.3	30	1.53	1.3%	1.6%
N3 to N2B	185	1	2 AWG	0.196	40	1.45	1.2%	1.5%
T-6 to N6	15	3	2/0 AWG	0.11	300	0.17	0.1%	-
N6 to N5B	185	1	6 AWG	0.462	25	2.14	1.8%	1.9%
N6 to N6B	170	1	6 AWG	0.462	20	1.57	1.3%	1.4%
T-2 to C2	15	3	300 mcm	0.064	800	0.26	0.2%	-
C2 to C1B	185	1	1/0 AWG	0.133	70	1.72	1.4%	1.6%
C2 to C2B	170	1	1/0 AWG	0.133	80	1.81	1.5%	1.7%
C2 to C3B	185	1	2/0 AWG	0.11	90	1.83	1.5%	1.7%
T-5 to C5	15	2	4/0 AWG	0.075	450	0.25	0.2%	-
C5 to C4B	185	1	2 AWG	0.196	50	1.81	1.5%	1.7%
C5 to C5B	170	1	4 AWG	0.3	40	2.04	1.7%	1.9%
C5 to C6B	185	1	2/0 AWG	0.11	90	1.83	1.5%	1.7%

With all the panels and distribution system sized, the system can be implemented and placed through the building. The new system, Riser 1, is contained on the next page. The following two pages after that are the final wire sizes after resizing for the main circuit breakers and voltage drops. Those are the wires that have been sized on the wiring diagram.

The transformer schedule and switchgear schedule that have been previously provided give the information for the distribution equipment on Riser 1.

Isolated Ground Panels 208/120

Panel	Existing KVA	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
C1 - sect1	57.4	44.7	124.1	155.1	225 A	175 A	(5) 2/0 AWG	(2) #4	2 - 1/2"
C1 - sect2	22								
C1B	30.2	20.1	55.8	69.7	100 A	70 A	(5) 1/0 AWG	(2) #6	2 - 1/2"
C2	384.5	197.3	547.5	684.4	800 A	800 A	*(5) 3/0 AWG	(2) #2	(3) 2 - 1/2"
C2B	32.2	21.1	58.6	73.2	100 A	80 A	(5) 1/0 AWG	(2) #6	2 - 1/2"
C3 - sect 1	66	58.3	161.8	202.3	225 A	225 A	(5) 4/0 AWG	(2) #2	3"
C3 - sect 2	40.6								
C3B	40.4	25.2	69.9	87.4	100 A	90 A	(5) 2/0 AWG	(2) #4	2 - 1/2"
C4	47.7	28.9	80.1	100.1	225 A	125 A	(5) 1 AWG	(2) #6	2"
C4B	17.6	13.8	38.3	47.9	100 A	50 A	(5) 2 AWG	(2) #8	2"
C5	234.6	122.3	339.5	424.3	600 A	450 A	**(5) 4/0 AWG	(2) #4	(2) 3"
C5B	10.9	10.5	29.0	36.3	100 A	40 A	(5) 4 AWG	(2) #8	1 - 1/2"
C6	71.3	40.7	112.8	141.0	225 A	150 A	(5) 1/0 AWG	(2) #6	2"
C6B	36.6	23.3	64.7	80.8	100 A	90 A	(5) 2/0 AWG	(2) #4	2 - 1/2"

208/120 Panels

Panel	Recepticle KVA	Motor Kva	Existing Kva	design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
NP2	17.47	79.03	96.5	92.765	257.5	321.9	400 A	350 A	** (4) 2/0 AWG	(1) #4	(2) 2-1/2"
N1	10.13	46.67	56.8	56.735	157.5	196.9	225 A	200 A	(4) 3/0 AWG	(1) #4	2 1/2"
N1B	1.58	8.62	10.2	10.2	28.3	35.4	100 A	40 A	(4) 8 AWG	(1) #8	1"
N2	7.92	15.58	23.5	23.5	65.2	81.5	100 A	90 A	(4) 3 AWG	(1) #8	1 - 1/4"
N2B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 2 AWG	(1) #8	1 1/2"
N3	49.98	44.32	94.3	74.31	206.3	257.8	400 A	300 A	** (4) 1/0 AWG	(1) #6	(2) 2"
N3B	2.34	1.06	3.4	3.4	9.4	11.8	100 A	15 A	(4) 8 AWG	(1) #8	1"
N4	19.22	12.78	32	27.39	76.0	95.0	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N4B	5.04	2.56	7.6	7.6	21.1	26.4	100 A	30 A	(4) 4 AWG	(1) #8	1 - 1/4"
N5	11.7	16.1	27.8	26.95	74.8	93.5	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N5B	5.04	1.06	6.1	6.1	16.9	21.2	100 A	25 A	(4) 6 AWG	(1) #8	1 -1/4"
N6	37.76	58.94	96.7	82.82	229.9	287.4	400 A	300 A	** (4) 1/0 AWG	(1) #6	(2) 2"
N6B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 6 AWG	(1) #8	1 -1/4"
NPH	1.8	3	4.8	4.8	13.3	16.7	100 A	20 A	(4) 8 AWG	(1) #8	1"

** Two wire runs
* Three wire runs

Values that are highlighted in yellow were resized because they were sized as main circuit breakers. The values in red were resized due to voltage drop runs.

Riser 2

My second design of the 208/120 distribution system involves leaving Switchgear NDP on the ground floor of the building, relocating one of the remaining Switchgears to the Penthouse level, and eliminating the remaining switchgear. This design is meant to split the loads into two portions of buildings, P2 to the 3rd floor and 4th floor to the penthouse. This attempt was designed to help split the distribute the loads more evenly in the building and attempt to negate some of the voltage drop through the wires.

The calculations for the second Riser were performed in the same way. The following pages contain the calculations that were discussed previously. After the panel sizing, wire sizing, transformer calculation, and voltage drop, there is a picture of the riser diagram and then the resized wires on the pages after that. All the calculations that were performed can be found on a spreadsheet which can be found with the attached CD.

Isolated Ground Panels 208/120

Panel	Existing KVA	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
C1 - sect1	57.4	44.7	124.1	155.1	225 A	175 A	(5) 2/0 AWG	(2) #4	2 - 1/2"
C1 - sect2	22								
C1B	30.2	20.1	55.8	69.7	100 A	70 A	(5) 4 AWG	(2) #8	1 - 1/2"
C2 - sect 1	58.6	52.9	146.7	183.4	225 A	200 A	(5) 3/0 AWG	(2) #4	2 - 1/2"
C2 - sect 2	37.1								
C2B	32.2	21.1	58.6	73.2	100 A	80 A	(5) 4 AWG	(2) #8	1 - 1/2"
C3 - sect 1	66	58.3	161.8	202.3	225 A	225 A	(5) 4/0 AWG	(2) #2	3"
C3 - sect 2	40.6								
C3B	40.4	25.2	69.9	87.4	100 A	90 A	(5) 3 AWG	(2) #8	1 - 1/2"
C4	47.7	28.9	80.1	100.1	225 A	125 A	(5) 1 AWG	(2) #6	2"
C4B	17.6	13.8	38.3	47.9	100 A	50 A	(5) 8 AWG	(2) #8	1 - 1/4"
C5	50.5	30.3	84.0	105.0	225 A	125 A	(5) 1 AWG	(2) #6	2"
C5B	10.9	10.5	29.0	36.3	100 A	40 A	(5) 8 AWG	(2) #8	1 - 1/4"
C6	71.3	40.7	112.8	141.0	225 A	150 A	(5) 1/0 AWG	(2) #6	2 - 1/2"
C6B	36.6	23.3	64.7	80.8	100 A	90 A	(5) 3 AWG	(2) #8	1 - 1/4"

MCB Isolated Wire Sizing.

Panel	Breaker	Wire Size	Ground Size	Conduit Size
C2	800 A	* (5) 300 MCM	(2) #2	(3) 3"
C5	450 A	**(5) #4/0 AWG	(2) #2	(2) 3"

** Two wire runs
* Three wire runs

208/120 Panels

Panel	Recepticle KVA	Motor Kva	Existing Kva	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
NP2	5.76	23.74	29.5	29.5	81.9	102.4	225 A	125 A	(4) 1 AWG	(1) #6	2"
N1	10.13	46.67	56.8	56.735	157.5	196.9	225 A	200 A	(4) 3/0 AWG	(1) #4	2 - 1/2"
N1B	1.58	8.62	10.2	10.2	28.3	35.4	100 A	40 A	(4) 8 AWG	(1) #8	1"
N2	7.92	15.58	23.5	23.5	65.2	81.5	100 A	90 A	(4) 3 AWG	(1) #8	1 - 1/4"
N2B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 8 AWG	(1) #8	1"
N3	12.4	6.7	19.1	17.9	49.7	62.1	100 A	70 A	(4) 4 AWG	(1) #8	1 - 1/4"
N3B	2.34	1.06	3.4	3.4	9.4	11.8	100 A	15 A	(4) 8 AWG	(1) #8	1"
N4	19.22	12.78	32	27.39	76.0	95.0	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N4B	5.04	2.56	7.6	7.6	21.1	26.4	100 A	30 A	(4) 8 AWG	(1) #8	1"
N5	11.7	16.1	27.8	26.95	74.8	93.5	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N5B	5.04	1.06	6.1	6.1	16.9	21.2	100 A	25 A	(4) 8 AWG	(1) #8	1"
N6	16.16	33.14	49.3	46.22	128.3	160.4	225 A	175 A	(4) 2/0 AWG	(1) #4	2"
N6B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 8 AWG	(1) #8	3/4"
NPH	1.8	3	4.8	4.8	13.3	16.7	100 A	20 A	(4) 8 AWG	(1) #8	3/4"

MCB Wire Sizing

Panel	Breaker	Wire Size	Ground	Conduit Size
N2	500 A	** (4) 250 MCM	(1) #2	(2) 1-1/2"
N5	300 A	** (4) 3/0 AWG	2 AWG	(2) 2 - 1/2"

Transformer Schedule

Xfrmer	Serving Panel	KVA Load	Xfrmer Size	Ampacity	Wire Size	Conduit
T-C2	C2	197.3	225	469.0	** 250 MCM	(2) 3"
T-N2	N2	134.6	150	312.6	** 2/0 AWG	(2) 1 - 1/2"
T-C5	C5	122.3	150	312.6	** 2/0 AWG	(2) 1 - 1/2"
T-N5	N5	110.29	150	312.6	** 2/0 AWG	(2) 1 - 1/2"

** Two wire runs

Voltage Drop for Long Runs

Run	Length	Number	Size	K	Ampacity	Volt drop	% Volt Drop	Base Drop
TN2 to N2	15	2	2/0 AWG	0.11	500	0.41	0.3%	-
N2 to NP2	58	1	1 AWG	0.162	125	1.17	1.0%	1.3%
N2 to N1B	185	1	8 AWG	0.699	40	5.17	4.3%	4.7%
N2 to N2B	170	1	8 AWG	0.699	40	4.75	4.0%	4.3%
N2 to N3B	185	1	8 AWG	0.699	15	1.94	1.6%	2.0%
T-N5 to N5	15	2	2/0 AWG	0.11	400	0.33	0.3%	-
N5 to N4B	185	1	8 AWG	0.699	30	3.88	3.2%	3.5%
N5 to N5B	170	1	8 AWG	0.699	25	2.97	2.5%	2.8%
N5 to N6B	185	1	8 AWG	0.699	40	5.17	4.3%	4.6%
N5 to NPH	50	1	8 AWG	0.699	20	0.70	0.6%	0.9%
T-N2 to C2	15	3	300 mcm	0.064	800	0.26	0.2%	-
C2 to C1B	185	1	4 AWG	0.3	70	3.89	3.2%	3.5%
C2 to C2B	170	1	4 AWG	0.3	80	4.08	3.4%	3.6%
C2 to C3B	185	1	3 AWG	0.3	90	5.00	4.2%	4.4%
T-C5 to C5	15	2	4/0 AWG	0.075	450	0.25	0.2%	-
C5 to C4B	185	1	8 AWG	0.699	50	6.47	5.4%	5.6%
C5 to C5B	170	1	8 AWG	0.699	40	4.75	4.0%	4.2%
C5 to C6B	185	1	3 AWG	0.196	90	3.26	2.7%	2.9%

Voltage Drop resizing

Run	Length	Number	Size	K	Ampacity	Volt drop	% Volt Drop	Base Drop
TN2 to N2	15	2	2/0 AWG	0.11	500	0.41	0.3%	-
N2 to N1B	185	1	2 AWG	0.196	40	1.45	1.2%	1.6%
N2 to N2B	170	1	4 AWG	0.3	40	2.04	1.7%	2.0%
T-N5 to N5	15	2	2/0 AWG	0.11	400	0.33	0.3%	-
N5 to N4B	185	1	4 AWG	0.3	30	1.67	1.4%	1.7%
N5 to N5B	170	1	6 AWG	0.462	25	1.96	1.6%	1.9%
N5 to N6B	185	1	2 AWG	0.196	40	1.45	1.2%	1.5%
T-2 to C2	15	3	300 mcm	0.064	800	0.26	0.2%	-
C2 to C1B	185	1	1/0 AWG	0.133	70	1.72	1.4%	1.6%
C2 to C2B	170	1	1/0 AWG	0.133	80	1.81	1.5%	1.7%
C2 to C3B	185	1	2/0 AWG	0.11	90	1.83	1.5%	1.7%
T-5 to C5	15	2	4/0 AWG	0.075	450	0.25	0.2%	-
C5 to C4B	185	1	2 AWG	0.196	50	1.81	1.5%	1.7%
C5 to C5B	170	1	4 AWG	0.3	40	2.04	1.7%	1.9%
C5 to C6B	185	1	2/0 AWG	0.11	90	1.83	1.5%	1.7%

Isolated Ground Panels 208/120

Panel	Existing KVA	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
C1 - sect1	57.4	44.7	124.1	155.1	225 A	175 A	(5) 2/0 AWG	(2) #4	2 - 1/2"
C1 - sect2	22								
C1B	30.2	20.1	55.8	69.7	100 A	70 A	(5) 1/0 AWG	(2) #6	2 - 1/2"
C2 - sect 1	384.5	197.3	547.5	684.4	800 A	800 A	* (5) 300 MCM	(2) #2	(3) 3"
C2B	32.2	21.1	58.6	73.2	100 A	80 A	(5) 1/0 AWG	(2) #6	2 - 1/2"
C3 - sect 1	66	58.3	161.8	202.3	225 A	225 A	(5) 4/0 AWG	(2) #2	3"
C3 - sect 2	40.6								
C3B	40.4	25.2	69.9	87.4	100 A	90 A	(5) 2/0 AWG	(2) #4	2 - 1/2"
C4	47.7	28.9	80.1	100.1	225 A	125 A	(5) 1 AWG	(2) #6	2"
C4B	17.6	13.8	38.3	47.9	100 A	50 A	(5) 2 AWG	(2) #8	2"
C5	234.6	122.3	339.5	424.3	600 A	450 A	** (5) 4/0 AWG	(2) #2	(2) 3"
C5B	10.9	10.5	29.0	36.3	100 A	40 A	(5) 4 AWG	(2) #8	1 - 1/2"
C6	71.3	40.7	112.8	141.0	225 A	150 A	(5) 1/0 AWG	(2) #6	2 - 1/2"
C6B	36.6	23.3	64.7	80.8	100 A	90 A	(5) 2/0 AWG	(2) #4	2 - 1/2"

208/120 Panels

Panel	Recepticle KVA	Motor Kva	Existing Kva	Design KVA	Ampacity	Sized up	Frame	Breaker	Wire Size	Ground Size	Conduit Size
NP2	5.76	23.74	29.5	29.5	81.9	102.4	225 A	125 A	(4) 1 AWG	(1) #6	2"
N1	10.13	46.67	56.8	56.735	157.5	196.9	225 A	200 A	(4) 3/0 AWG	(1) #4	2 - 1/2"
N1B	1.58	8.62	10.2	10.2	28.3	35.4	100 A	40 A	(4) 2 AWG	(1) #8	1 - 1/2"
N2	43.19	108.01	151.2	134.61	373.6	467.0	600 A	500 A	** 250 MCM	(1) #2	(2) 2 - 1/2"
N2B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 4 AWG	(1) #8	1 - 1/4"
N3	12.4	6.7	19.1	17.9	49.7	62.1	100 A	70 A	(4) 4 AWG	(1) #8	1 - 1/4"
N3B	2.34	1.06	3.4	3.4	9.4	11.8	100 A	15 A	(4) 8 AWG	(1) #8	1"
N4	19.22	12.78	32	27.39	76.0	95.0	100 A	100 A	(4) 3 AWG	(1) #8	1 - 1/4"
N4B	5.04	2.56	7.6	7.6	21.1	26.4	100 A	30 A	(4) 4 AWG	(1) #8	1 - 1/4"
N5	62.02	74.28	136.3	110.29	306.1	382.7	400 A	400 A	** (4) 3/0 AWG	(1) #2	(2) 2 - 1/2"
N5B	5.04	1.06	6.1	6.1	16.9	21.2	100 A	25 A	(4) 6 AWG	(1) #8	1 - 1/4"
N6	16.16	33.14	49.3	46.22	128.3	160.4	225 A	175 A	(4) 2/0 AWG	(1) #4	2"
N6B	3.06	5.64	8.7	8.7	24.1	30.2	100 A	40 A	(4) 2 AWG	(1) #8	1 - 1/2"
NPH	1.8	3	4.8	4.8	13.3	16.7	100 A	20 A	(4) 8 AWG	(1) #8	3/4"

** Two wire runs
* Three wire runs

Values that are highlighted in yellow were resized because they were sized as main circuit breakers. The values in red were resized due to voltage drop runs.