Section 3 – Electrical Depth Work

3.1 Emergency Data Recovery System

The NIMO power corporation, supplying power to the city of Utica and surrounding areas, serves approximately 134,000 business customers. In 2004, the area had a total of 1,598 electrical interruptions totaling 401,301 hours. In 1996, the area suffered from an ice storm that resulted in a regional power loss for 3 weeks. Commonly, the area loses power for at least one 24-48 hour period each year due to storms (information from Niagara Mohawk Power Corporation).

Because of the vast size of Thomas R. Proctor High School and the fact that it is the lone high school in the district of Utica (located near the downtown area) I have investigated the plan of adapting the building to serve electrically as an emergency data recovery epicenter for businesses in the community and K-8 grade schools in the district. The volume of the building allows for such outside institutions to temporarily set up vital equipment within the high school in times of natural disaster, power loss, or other events. In the design, the usually vacant auxiliary gymnasiums have been converted into localized data epicenters to be able to assist a centralized group. To accompany additional groups, many of the classrooms in the school have also been supported.

Upon the initial design of the new emergency system, the first point to be addressed is exactly which areas of the school should be backed with emergency power. Since the intent of the recovery system is to support computer loads, I proposed a design in which all of the clean power panels in the school would be supported. This would not only allow for the optimal amount of outside workers to set up equipment throughout the school, but it would also handle all of the computer equipment of the present staff and employees of the school. Although the main focus of the design is to provide a localized recovery site in the two auxiliary gymnasiums, additional backup of all of the clean power in the school would account for any extra spillover of people.

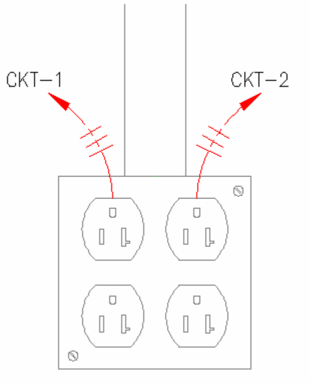
After determining which of the new and existing areas are to be backed with emergency power, the next step is determining the necessary equipment and its arrangement in the new emergency power scheme. The new design will consist of an automatic transfer switch, additional generator, an uninterruptible power supply, transformer, and distribution panels. A detailed description of the equipment and emergency power procedure is given in the Equipment Description and Procedure section.

3.1.1 Design Layout and Load Calculations

Auxiliary Gymnasiums

The new electrical design involves providing clean emergency power to each of the two adjacent auxiliary gymnasiums. Auxiliary Gym 1 is located on the first floor of Sector G and is part of the original school. Auxiliary Gym 2 is situated next to Auxiliary Gym 1 at the ground level. This new gym is part of the newest addition to the high school.

Although neither of the two spaces is used as the primary gymnasium (the main gymnasium is located in Sector F), the electrical design in each of the auxiliary gymnasiums has to take into account the main function of the space as a recreational area. As a result, many limitations arise on the available locations for receptacles. Since floor receptacles are not an option, a design has to be implemented that would maximize the available areas for receptacles. Because both gyms have CMU walls, the new design utilizes conduit and surface mounted double duplex receptacle boxes spaced approximately every 14 feet along the walls. Every receptacle will have its own dedicated circuit (two circuits per receptacle box). This arrangement will allow for each receptacle to tolerate a very large load while minimizing the amount of conduit and receptacles.



Receptacle circuiting

Due to the reduced number of receptacles in the gymnasiums, there is a significant amount of coordination among the school personnel that is necessary. Specifically, tables, chairs, surge protecting power strips, and extension cords would be needed to get the maximum use of the gyms. Coordination would also be necessary to determine how many people could efficiently conduct their work in the two gymnasiums. There are many different seating arrangements that could be viable for temporary equipment set up. The setup in the following circuiting plans assumes that each receptacle is designated to a table. Therefore, two people at each table would share a receptacle (most efficiently executed with a power strip at each receptacle.) This specific sample layout would allow for 48 people to be situated in Gym 1 and 64 people in Gym 2. At maximum capacity, 72 people can work in Gym 1 and 96 people in Gym 2 (a total of 168 people, assuming 3 people per receptacle operating at no more than 5 amps each).

A panelboard will be placed in close proximity to each gymnasium. In Gym 1, panelboard CP1G is located in the locker room attached to the gym. In Gym 2, panelboard CPGG is located in the equipment room of the gymnasium. To determine the total connected load and demand load in each space for panelboard sizing, several assumptions were made for both spaces:

1. Since the electrical design of the two gyms is intended to handle a very large load at a single time, a demand factor of 1 was used to size the panelboards. Therefore, the total connected load and demand load will equal for each gym.
2. Each circuit was assumed to have a load of 15 amps (3 computer stations at 5 amps per computer).
3. A power factor of .85 was used for both spaces.
4. A future growth factor of 25% was used for both spaces.

Total Connected Load/Demand Load – Gym 1: 43.20 kVA
+ 10.80 kVA (25% growth)
54.00 kVA

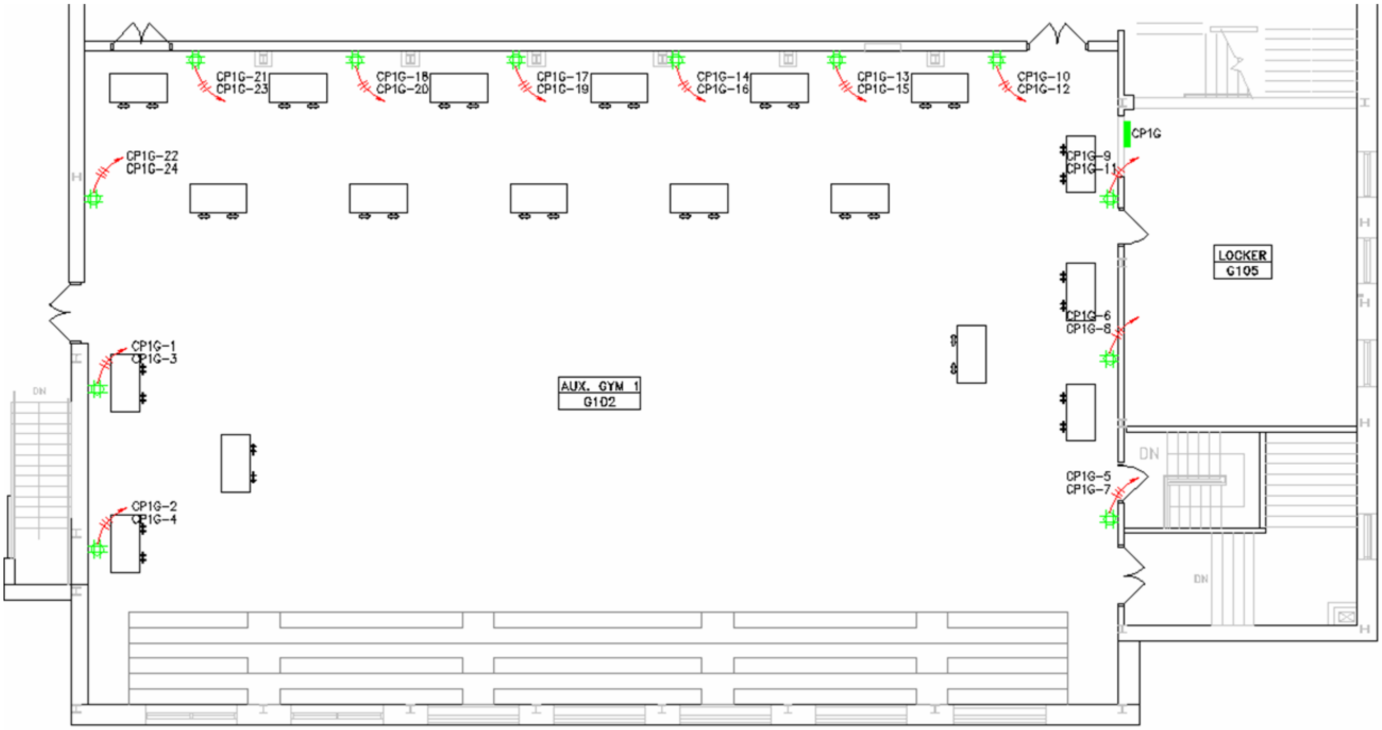
54.00 kVA/(1.732)(.208) **= 150A**

Panelboard CP1G Main Breaker: **225A**

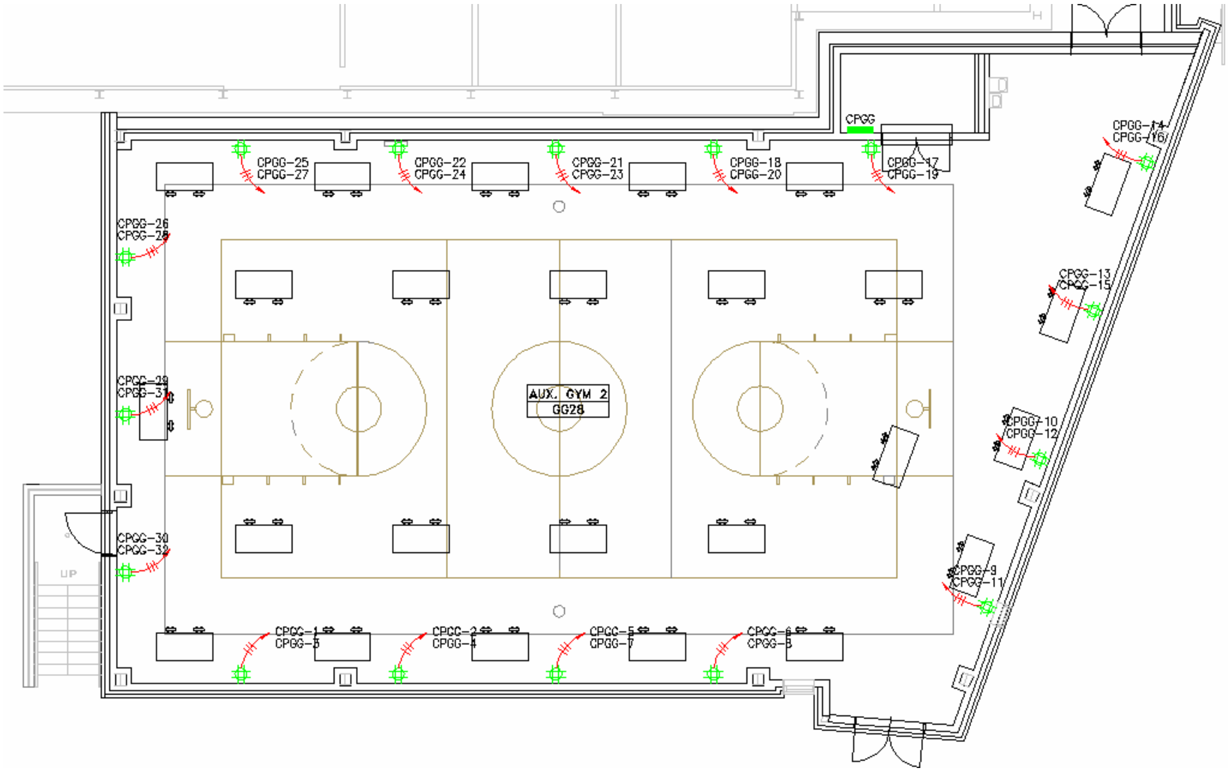
Total Connected Load/Demand Load – Gym2: 57.60 kVA
+ 14.40 kVA (25% growth)
72.00 kVA

72.00 kVA/(1.732)(.208) **= 200A**

Panelboard CPGG Main Breaker: **225 A**



Auxiliary Gym 1 – First Floor - Circuiting Plan and Sample Furniture Arrangement



Auxiliary Gym 2 – Ground Floor - Circuiting Plan and Sample Furniture Arrangement

New Panelboard Schedules

DESIGNATION: CP1G	VOLTAGE: 208/120V-3ø-4W	LOCATION: LOCKER G105
	MAINS: 225 AMP MAIN BREAKER	FED BY: ECP-1
	TYPE: CLEAN POWER	
	O.C. DEVICE: CIRCUIT BREAKER	MINIMUM O.C. DEVICE INTERRUPTING RATING: 10,000 AIC
	MOUNTING: SURFACE	

Description	CKT.	O.C. AMP	P	KVA Ø A		KVA Ø B		KVA Ø C		P	O.C. AMP	CKT.	Description
RECEPTACLE – AUXILIARY GYM 1	1	20	1	1.8	1.8					1	20	2	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	3	20	1			1.8	1.8			1	20	4	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	5	20	1					1.8	1.8	1	20	6	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	7	20	1	1.8	1.8					1	20	8	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	9	20	1			1.8	1.8			1	20	10	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	11	20	1					1.8	1.8	1	20	12	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	13	20	1	1.8	1.8							14	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	15					1.8	1.8					16	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	17							1.8	1.8			18	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	19			1.8	1.8							20	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	21					1.8	1.8					22	RECEPTACLE – AUXILIARY GYM 1
RECEPTACLE – AUXILIARY GYM 1	23							1.8	1.8			24	RECEPTACLE – AUXILIARY GYM 1
	25											26	
	27											28	
	29											30	
	31											32	
	33											34	
	35											36	
SPARE	37	20	1							1	20	38	SPARE
SPARE	39	20	1							1	20	40	SPARE
SPARE	41	20	1							1	20	42	SPARE
			TOTAL KVA/ø	14.4		14.4		14.4				TOTAL KVA	43.2

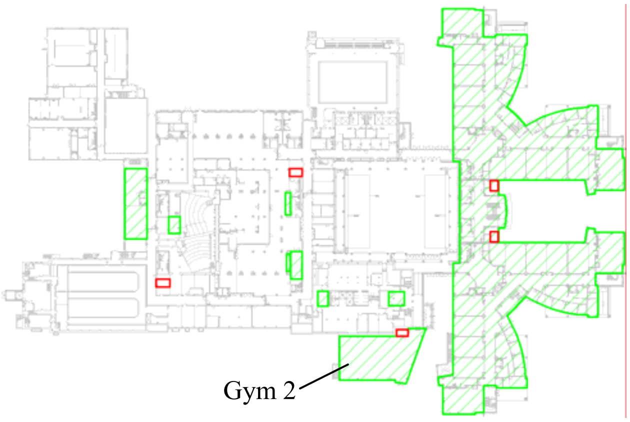
DESIGNATION: CPGG	VOLTAGE: 208/120V-3ø-4W	LOCATION: AUXILIARY GYM GG28
	MAINS: 225 AMP MAIN BREAKER	FED BY: ECP-1
	TYPE: CLEAN POWER	
	O.C. DEVICE: CIRCUIT BREAKER	MINIMUM O.C. DEVICE INTERRUPTING RATING: 10,000 AIC
	MOUNTING: SURFACE	

Description	CKT.	O.C. AMP	P	KVA Ø A		KVA Ø B		KVA Ø C		P	O.C. AMP	CKT.	Description
RECEPTACLE – AUXILIARY GYM 2	1	20	1	1.5	1.5					1	20	2	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	3	20	1			1.8	1.8			1	20	4	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	5	20	1					1.8	1.8	1	20	6	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	7	20	1	1.8	1.8					1	20	8	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	9	20	1			1.8	1.8			1	20	10	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	11	20	1					1.8	1.8	1	20	12	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	13	20	1	1.8	1.8					1	20	14	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	15	20	1			1.8	1.8			1	20	16	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	17	20	1					1.8	1.8	1	20	18	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	19	20	1	1.8	1.8					1	20	20	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	21	20	1			1.8	1.8			1	20	22	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	23	20	1					1.8	1.8	1	20	24	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	25	20	1	1.8	1.8					1	20	26	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	27	20	1			1.8	1.8			1	20	28	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	29	20	1					1.8	1.8	1	20	30	RECEPTACLE – AUXILIARY GYM 2
RECEPTACLE – AUXILIARY GYM 2	31	20	1	1.8	1.8					1	20	32	RECEPTACLE – AUXILIARY GYM 2
	33											34	
	35											36	
SPARE	37	20	1							1	20	38	SPARE
SPARE	39	20	1							1	20	40	SPARE
SPARE	41	20	1							1	20	42	SPARE
			TOTAL KVA/ø	21.6		18		18				TOTAL KVA	57.6

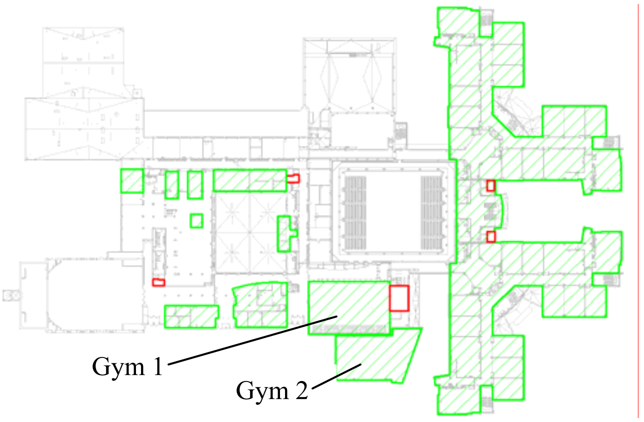
Classrooms/Offices

Since all of the clean power panels in the school are on emergency power, the design also allows many classrooms, offices and other spaces throughout the school to be converted into emergency recovery sites in times of need. Nearly every room in the newest addition to the school (consisting of all floors of sectors H, J, K) is backed by the new generator. In addition, many spaces in the older section of the building are supported under the new design:

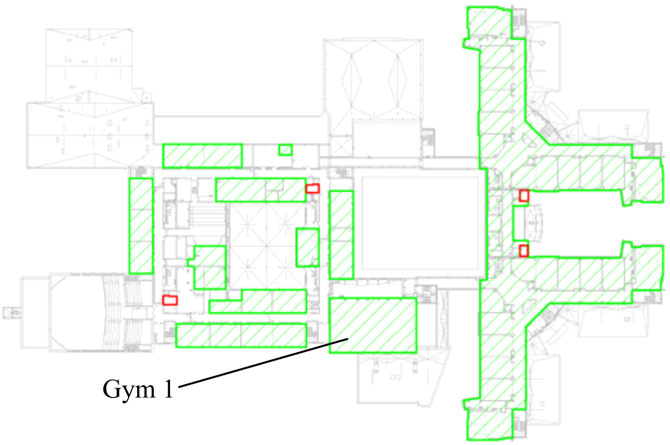
1. Ground Floor – music classroom, life skills office, training room, cafeteria computers, and general office
2. First Floor – library, general classrooms, teacher workroom, computer room, nurse area, conference rooms, community outreach room, reception area, staff workroom, principal's office
3. Second Floor – general classrooms, student activities rooms, department head classroom, computer classrooms, social studies workroom, foreign language classrooms, television production studios, faculty workroom
4. Third Floor – ceramics/sculpture room, art gallery/studio, business classrooms, math faculty workrooms, department head offices, drawing/painting studios



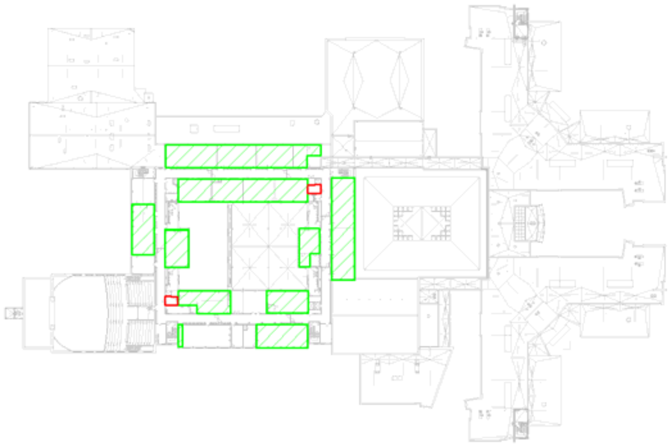
Ground Floor
🟥 Main areas housing existing clean power panels
🟩 Emergency areas



First Floor
🟥 Main areas housing existing clean power panels
🟩 Emergency areas



Second Floor
🟥 Main areas housing existing clean power panels
🟩 Emergency areas



Third Floor
🟥 Main areas housing existing clean power panels
🟩 Emergency areas

The clean power receptacles throughout the school were added to determine the total connected load and demand load. Although all of this clean power in the labeled emergency areas is to be backed with emergency power, it is unlikely that all of the areas would be used simultaneously in times of emergency. As a result, a demand factor of .5 is used for all receptacle loads over 10 kVA. A power factor of .85 was used for calculations.

Panel	CPGH	CP1H	CP2H	CPGK	CP1K	CP2K	CPGC	CP1C
Load (kVA)	56.5	50	46.5	55	46	34.5	19	36

Panel	CP2C	CP3C	CPGD	CP1D	CP2D	CP3D	F301	C215
Load (kVA)	10.5	18.9	16.5	19.5	30	19.5	21	21
Panel	**C301**	**C302**	**C303**	**D201**	**D202**	**D203**		
Load (kVA)	27	22.5	22.5	19.5	21	21		

Total connected kVA in emergency designated areas as determined from the connected load of each clean power panel on the new emergency system

Total Connected Load – Classrooms/Offices:
633.9 kVA @ .85 pf = 538.86 + j333.85 kVA
Total Demand Load:
(8.5 + j5.27 kVA) **(1st 10 kVA)**
(530.36 + j328.58) x (.5) = (265.18 + 164.29 kVA) **(remaining kVA)**

(8.5 + j5.27) kVA
+ (265.18 + 164.29) kVA
273.68 + j169.56 kVA = **321.95 kVA**

Due to the demand factor applied to the loads in the classroom/office areas in the school, it is important to make sure the load used in an emergency does not exceed the demand load. A safe estimate for the number of people who can conduct their work without overloading the emergency system is 80% of the demand load. Therefore, it is has been estimated that 450 people outside of the centralized gymnasiums can work safely on computers in any of the areas labeled "emergency areas" (assuming 600 VA/person). The specific areas to locate outside workers would be coordinated by personnel of the school.

Total Emergency System Load

@ .85 power factor:
(36.72 + j22.75 kVA) (Gym 1)
(48.96 + j30.34 kVA) (Gym 2)
+ (273.68 + j164.29 kVA) (Classrooms/Offices)
359.36 + j217.38 = **420 kVA**

Although the new emergency system requires 420 kVA demand load, only 228 kVA of the demand load is from what is presently on switchboard 1. Since the new switchboard 2 is rated for 3000A, the additional demand load would only increase the total demand load on the switchboard to 2266A. This still leaves 25% capacity for future growth; therefore, switchboard 2 was chosen to support the new system.

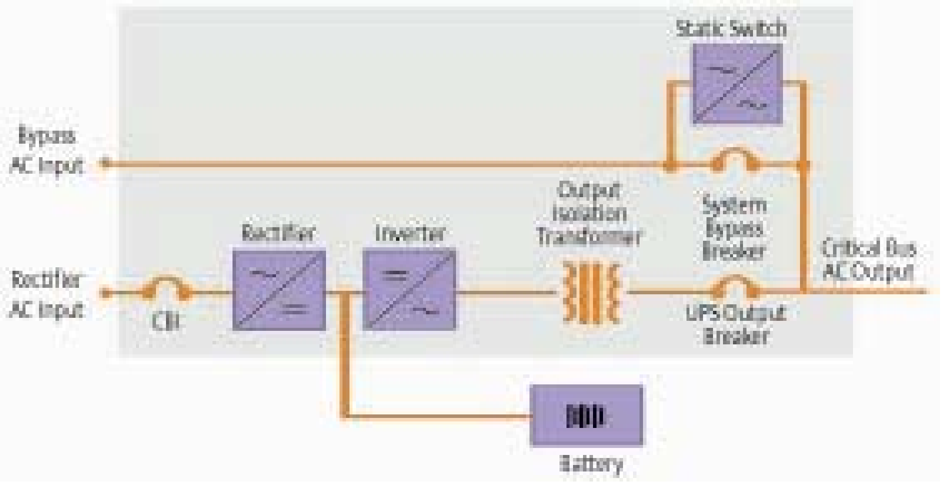
3.1.2 Equipment Description, Procedure, and Layout

After determining the layout and demand load of the new emergency system, equipment must be specified and arranged to carry out the new scheme (refer to the appendix for a full single-line diagram of the school incorporating the design).
The following is a list of the equipment necessary to carry out the design:

UPS System

As is typical with most emergency data recovery centers, added redundancy is necessary to ensure that power is always present. As a result, a UPS was incorporated into the design.

The main purpose of a UPS (uninterruptible power supply) is to provide immediate power to a system in times of source failure. Under normal condition, the specified UPS receives AC utility power and converts it to DC through a rectifier. This DC power then charges a battery pack that is in a cabinet attached to the UPS. The DC power is converted back to AC via an inverter and filtered through an output isolation transformer before it is delivered to the system. Upon power failure (AC power loss), the uninterrupted power would temporarily pick up the system load until the generator is fully synchronized to power the system. When the generator or utility power is operational, the UPS is transferred back into normal operation and begins recharging the battery pack. The standard features on the UPS include a backlit LCD display panel, an internal bypass for fault current, automatic retransfer, emergency power off, and a static switch to be able to bypass the battery cabinet for maintenance.



Single Module UPS configuration

There are many options for batteries, battery monitoring, and energy storage for UPS systems. The specified UPS contains 240 cells of lead acid

batteries that can support 125% of the full load for 10 minutes (generator is specified to be fully operational within 10 seconds). Since 125% of the full load is an unlikely scenario for this particular case, 30 minutes would be a more appropriate estimation for battery time. This should provide ample time to get the generator running if it was to fail. However, if further backup time is desired, the UPS has the ability for additional equipment to be added. Multiple battery packs can be added to the system through paralleling cabinets. Additionally, a flywheel energy storage system can be used to supplement battery packs. Such a backup enhancement would provide 20 seconds of backup (enough time to protect against short interruptions), allowing the batteries to be saved for long interruptions and improving battery life and reliability.

The UPS was sized according to the entire demand load of the new emergency system. Since the design of the new system addresses the maximum amount of computer loads to be in use at one time, there is no need to allow for much future growth of these types of loads. As a result, a 500 kVA UPS was chosen (420 kVA demand load) for the system.

Static Bypass Switch

Although the UPS allows for further redundancy in the system, protection still must be implemented in case the UPS system was to fail. Such occasions would be if the UPS received a large power surge (lighting) or more commonly when the batteries discharge after a potential generator failure. For such occurrences, it is necessary to be able to perform maintenance on the UPS without losing the loads downstream. A 600A static bypass switch was designed for such instances. The switch, normally in the open position, would close any time the UPS would lose power. This process would occur within 4 milliseconds and prevent the loads served by the UPS from losing power when the UPS is down or is being serviced.

Distribution Panelboards

EMDP

The UPS was incorporated into the design to support all of the clean power, however there may be emergency equipment added in the future that will not need to be backed by the UPS. For example, the design counts on the existing emergency lighting throughout the school to suit the set up of outside workforce. In case additional emergency lighting is desired, a setup must be in place to supply additional power. As a result, a 480/277V, 800A main emergency

distribution panelboard EMDP was selected to handle all of the emergency loads. The specified panel allows for complete flexibilitiy with the ability to place any size branch breaker (up to the size of the main breaker rating) next to a 15A breaker. Therefore, smaller load circuits, such as lighting, can be in the same panel as the breaker serving the new emergency clean power panel. Also, each breaker can mount anywhere on the vertical bus of the panel, independent of other breakers.

ECP1

Panel ECP1, which serves the entire emergency data recovery system, is fed from panel EMDP and is backed by the UPS system. This 1200A panel (the same type of panel as EMDP) effectively feeds all of the 24 clean power panels in the school and directly feeds 8 main panels in the building. This new design arrangement isolates the emergency clean power from the rest of the power on the system.

Transformer

Since panel EDMP is operating at 480/277V to account for additional loads, such as lighting, a transformer will be necessary to step down to a usable 208/120V. The existing 480V-480V output isolation transformer on the UPS eliminates common noise, transients, and harmonics on the system. As a result, the step-down transformer does not need to be an isolation transformer. Instead, a 500 kVA k-13 factor rated transformer was chosen. The specified k-rated transformer is designed for non-linear loads, such as personal computers, which standard transformers cannot handle. It is manufactured with heavy gauge copper and a double sized neutral conductor, which enables it to handle heat generated by harmonic current.

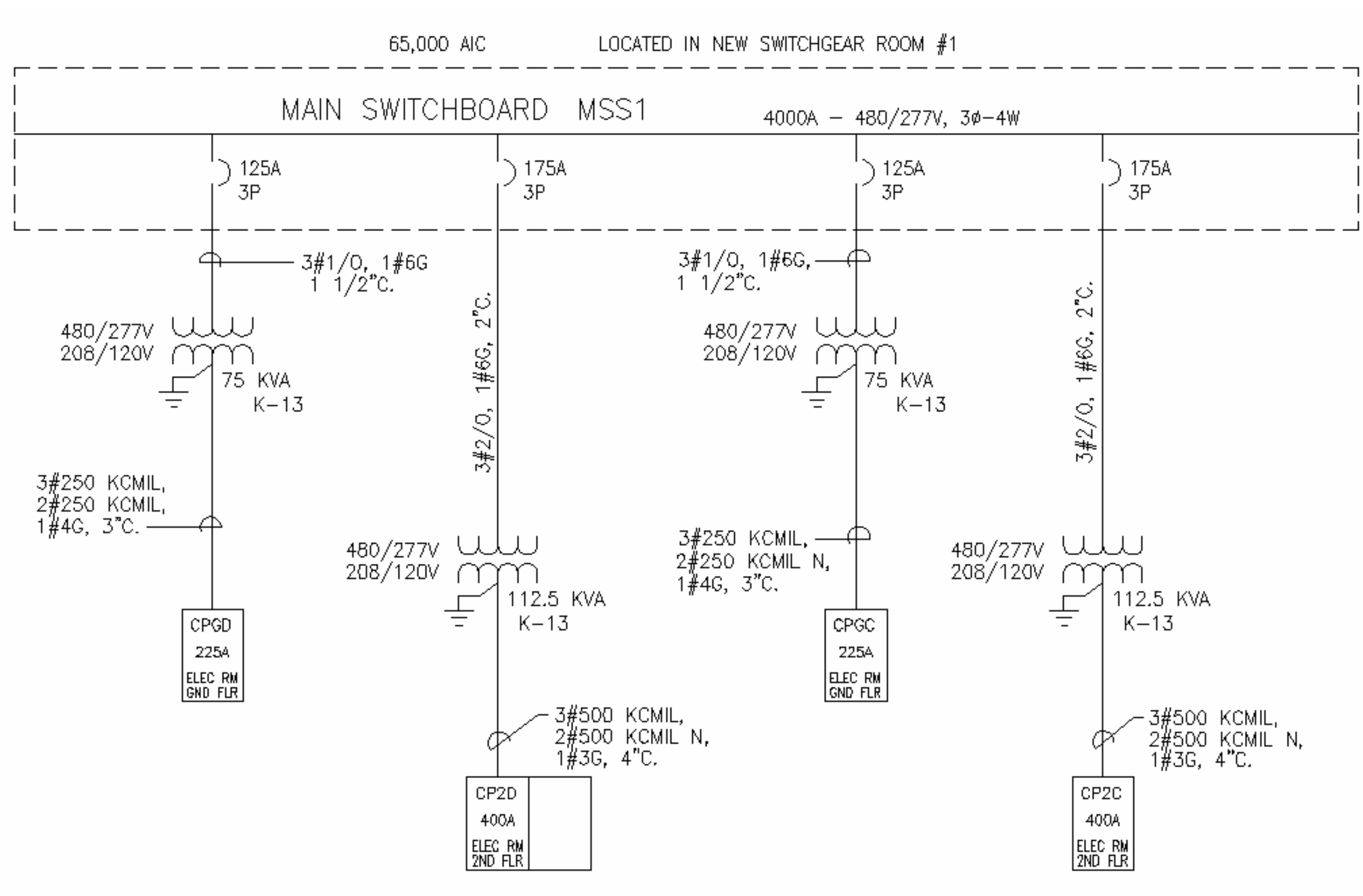
ATS

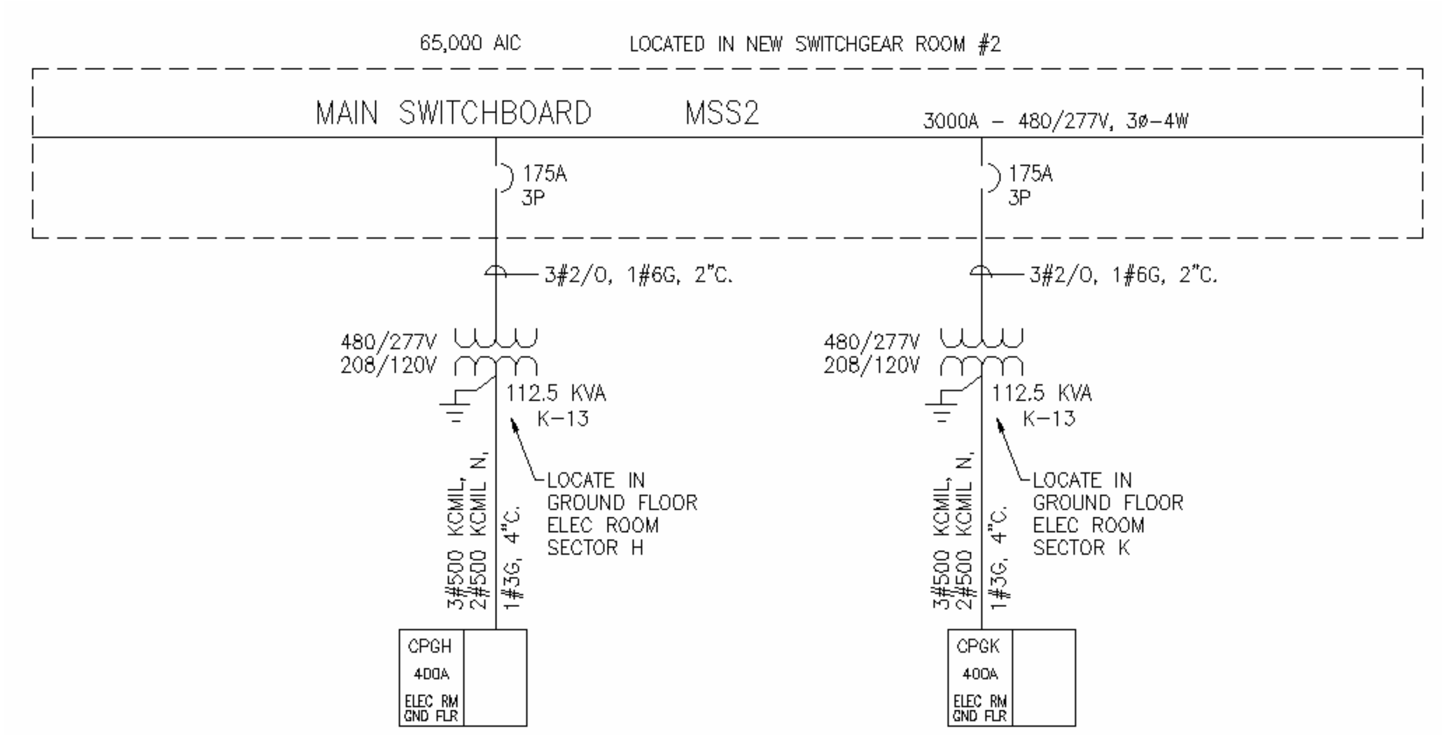
In order to transfer from normal power to emergency generator power in times of emergency, an automatic transfer switch is necessary. The ATS senses loss of utility power and switches to generator power. The specified 800A ATS offers many user-programmable options regarding voltage sensitivity and time delays. Upon power failure, the ATS offers an adjustable 0-5 minute transfer time delay to generator power (there is a manual override push button to bypass the time delay). An adjustable 0-30 minute time delay is also provided upon return to normal power. This time delay for retransfer will be automatically bypassed upon generator failure if normal power is acceptable.

Generator

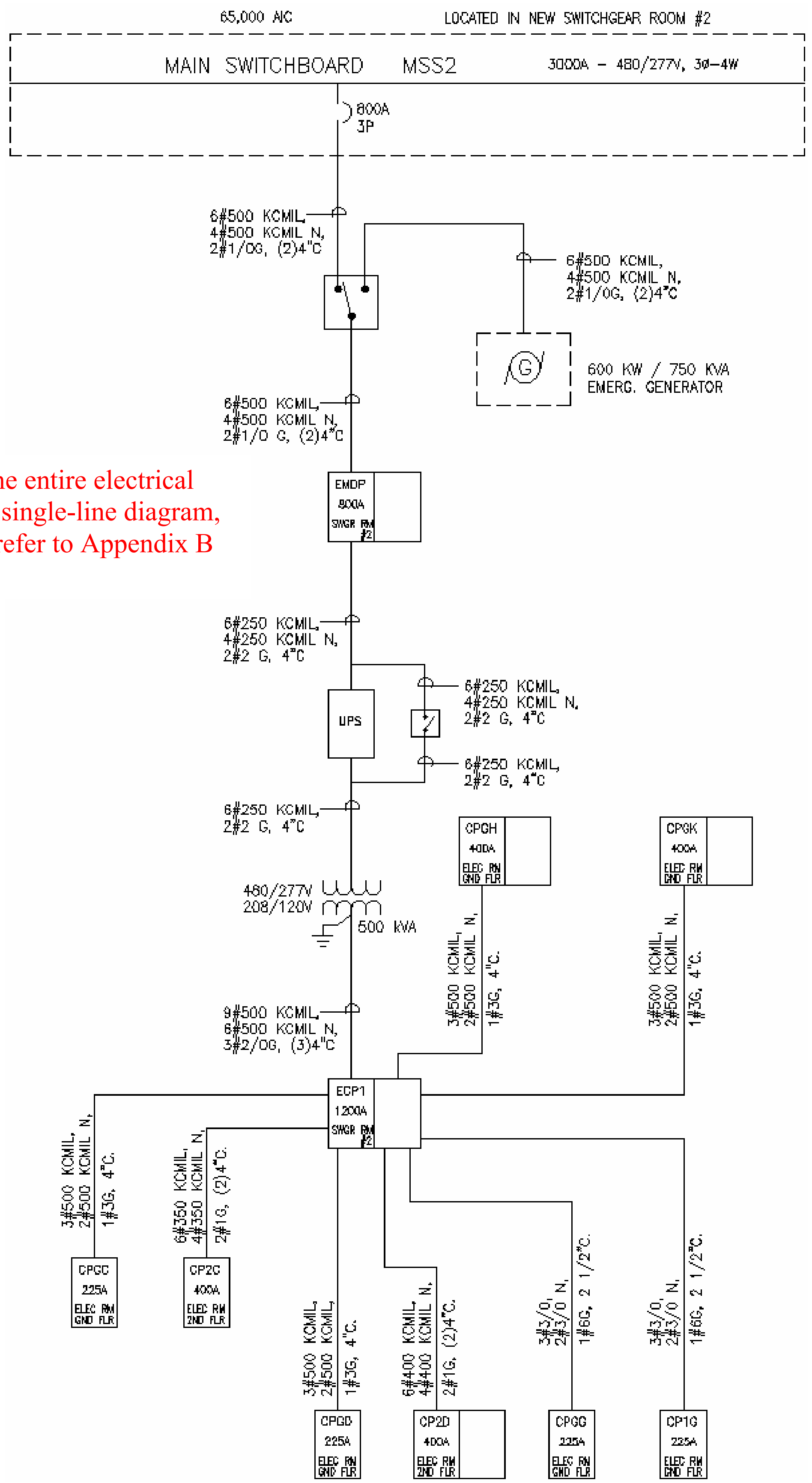
Different options existed for the emergency power generation for the new emergency recovery plan. One possibility would be to resize the existing 500kW/625 kVA diesel fuel generator to serve the new emergency system. However, since this existing generator backs life safety loads and has specialized shunt trip for load shedding in emergency situations, it would be more cumbersome to add loads and resize the generator than to design a new system. Therefore, a new 600kW/750 kVA diesel generator was sized to manage the new load. Since the demand load is 420 kVA, this generator would only be loaded to 56% of its capacity under expected emergency conditions. This would allow for considerable growth in the future. The specified generator has a selectable alternator, electronic control system, cooling system, and skid base. In addition to the generator, a diesel fuel tank must be sized to provide fuel to the generator. The fuel tank specified is a 780 gallon fuel tank that will provide 24 hours of fuel at 75% load. At 50% load, the fuel tank could provide 33 hours of fuel.

Emergency System Single-Line Diagrams





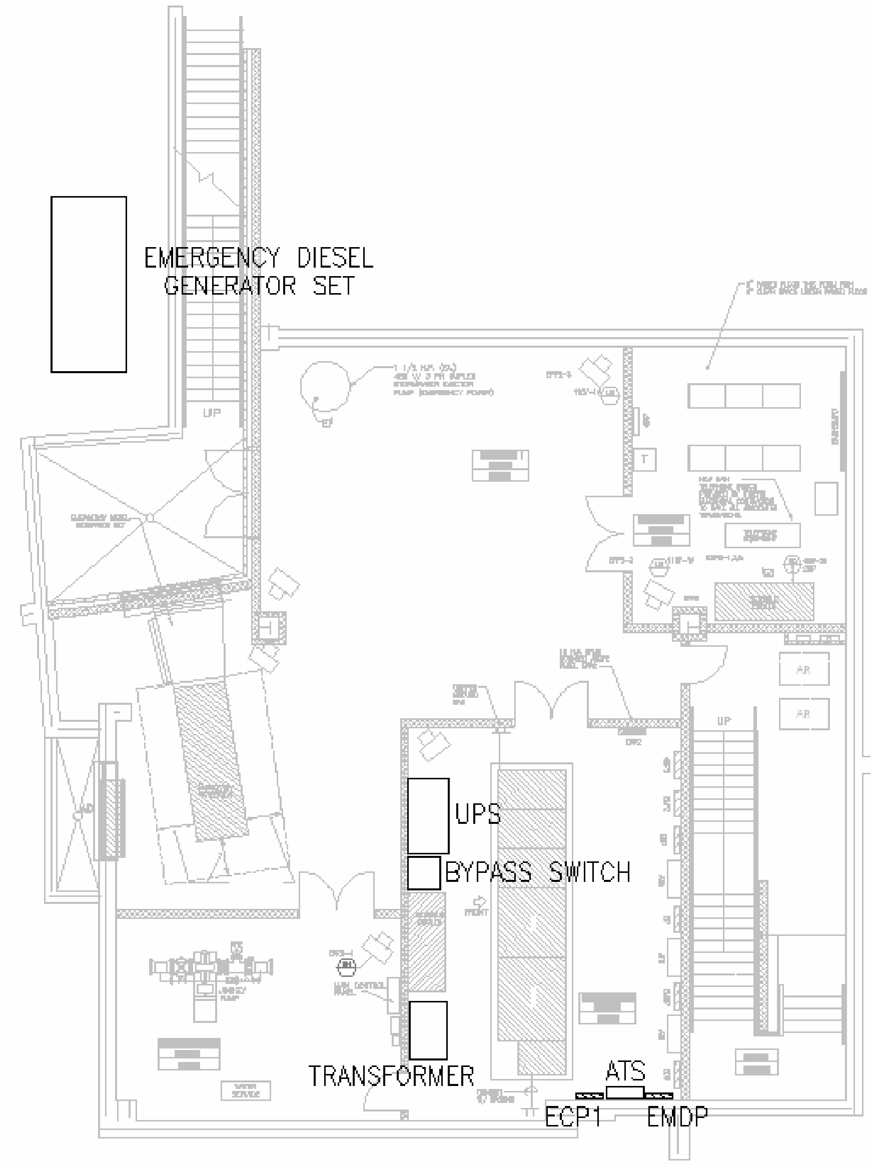
Portion of Existing System to Be Changed



* For the entire electrical system single-line diagram, please refer to Appendix B

Equipment Location

The added equipment in the new design would successfully fit in the new main switchboard room. According to code, there must be three feet of space for access to the new UPS, transformer, ATS, and distribution panelboards. Due to the close proximity of the generator to the school, it would be necessary to house the generator and fuel tank in a steel sound attenuated enclosure with door latches.



Equipment Location Plan

3.1.3 Equipment Feeder Sizing

The following is a list of the feeder and conduit sizes for the new equipment in the emergency system. Additionally, several existing panels that are now being fed from panel ECP1 needed to be resized due to a large voltage drop. Two neutrals (the same size as the phase conductors) were run with each set of feeders. This was done to account for the harmonic current that is commonly associated with non-linear loads such as computers. Results of feeder and conduit sizes for the equipment are as follows:

Equipment	Model #	Feeder Size	Conduit Size
ASCO Series 300 800A ATS	300B3800NIC	(2) 5#500 KCMIL, 1#1/0G	(2) 4"
Liebert Series 610 500 kVA UPS	SL-25142	(2) 5#250 KCMIL, 1#2G	4"
Square D 800A I-Line Panelboard	HCM-800A MCB	(2) 5#500 KCMIL, 1#1/0G	(2) 4"
Square D 1200A I-Line Panelboard	HCR-U-1200A MCB	(3) 5#500 KCMIL, 1#2/0G	(3) 4"
Square D NLP 480/277V - 208/120V Transformer	500T90HSFISNLP	(2) 3#250 KCMIL,1#2G	4"
Panel CPGC	Existing	(1) 5#500 KCMIL, 1#3 G	4"
Panel CP2C	Existing	(2) 5#350 KCMIL, 1#1G	(2) 4"
Panel CPGD	Existing	(1) 5#500 KCMIL, 1#3 G	4"
Panel CP2D	Existing	(2) 5#400 KCMIL, 1#1G	(2) 4"
Panel CPGG	Existing	(1) 5#3/0, 1#6G	(1) 2-1/2"
Panel CP1G	Existing	(1) 5#3/0, 1#6G	(1) 2-1/2"

3.1.4 Fault Current Analysis

In order to properly rate the equipment in the new recovery system, it is necessary to perform a short-circuit analysis. I have chosen the longest path through the new emergency system, from the main switchboard transformer to panel CP2D. The fault current for each piece of equipment was sized using Electrical Designer's Reference (EDR) fault current calculator software. The following assumptions were made in the analysis:

1. 1500 kVA transformer : %Z=3.5%
2. 500 kVA transformer: %Z=1.3%

The results from the fault current analysis are as follows:

Equipment	Feeder Size	Length (feet)	Isc	AIC Rating
1500kVA 13.2kV-480V Transformer	3#3/0 15kV	--	51,551	65,000
Switchboard 2	(5) 4#500 kcmil	10	50,701	65,000
Panel EMDP	(2) 5#500 kcmil	20	54,000	65,000
500kVA 480V-208V Transformer	(2) 3#250 kcmil	20	39,836	45,000
ECP1	(3) 5#500 kcmil	20	36,226	45,000
CP2D	(2) 5#400 kcmil	533	7,380	10,000

3.1.5 Equipment Cost

The following is a price estimate of the equipment for the new system:

Equipment	Quantity	Price/Quantity ($)	Labor	Total Price	Total Price w/ Labor
Cummins Power 600kW / 750kVA Generator	1	108,997	4,700	108997	113697
TAW Power Systems 600kW Fuel Tank	1	4,707	4450	4707	9157
ASCO Series 300 800A ATS	1	4,503	200	4503	4703
Liebert Series 610 500 kVA UPS (including bypass switch)	1	129,119.40	18,240	129119.4	147359.4
Square D NLP 480/277V - 208/120V Δ-Y Transformer	1	56,530	11,200	56530	67730
Square D 800A I-Line Panelboard	1	9,701	960	9701	10661
Square D 1200A I-Line Panelboard	1	11,675	960	11675	12635
CPGG 225A Panelboard (42 Circuit)	1	1025	960	1025	1985
CPG1G 225A Panelboard (42 Circuit)	1	1025	960	1025	1985
EMDP 600A Type LI Circuit Breaker	1	6,438	2702	6438	9140
ECP1 225A TYPE LH Circuit Breaker	4	3,714	945	14856	18636
ECP1 400A TYPE LH Circuit Breaker	4	4,627	1,654	18508	25124
3/0 copper cable (feet)	2672	1.46	1.3	3901.12	7374.72
250 kcmil copper cable (feet)	100	2.16	1.63	216	379
350 kcmil copper cable (feet)	952	2.97	1.81	2827.44	4550.56
400 kcmil copper cable (feet)	1066	3.4	1.92	3624.4	5671.12
500 kcmil copper cable (feet)	1289	4.2	2.04	5413.8	8043.36
2-1/2" EMT (feet)	2672	2.94	3.14	7855.68	16245.76
4" EMT	3407	5.67	5.02	19317.69	36420.83
				410240.53	501497.75
TOTAL				**$410,240.53**	**$501,497.75**

If the new system is implemented, the cost would likely be assessed by the Utica City School District. The 9 elementary schools and 2 middle schools in the school district would pay for at least a portion of the cost. Other cost options include a contractual agreement with the outside businesses that might use the school in times of emergency.

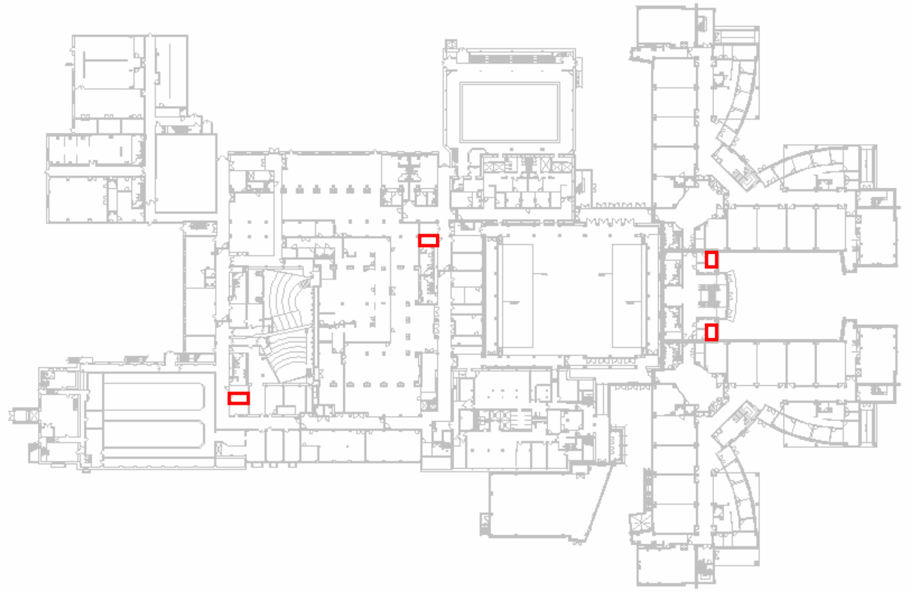
3.2 Bus Duct vs. Conduit/Cable

Since Thomas R. Proctor High School has various locations of stacked electrical closets, an analysis was done to decide whether or not vertical bus duct would have been a better solution than the decided cable/conduit system in these closets.

Bus duct is made up of a copper or aluminum conductor that is completely enclosed to ensure for protection against mechanical damage and dust accumulation. The conductors inside bus duct can be a bar type conductors or round cable conductors. Bus duct is commonly used in areas where there is limited space or multiple conduit runs may be obtrusive. Overall, bus duct holds several advantages over a normal cable/conduit system:

1. takes up less space, lighter and more aesthetically pleasing
2. lower impedance and voltage drop
3. convenient installation
4. larger short-circuit capacity
5. easy maintenance

A comparison was made based on the cost of implementing both systems in the four stacked electrical close locations. The electrical closets in sector C and sector D span 4 floors. The electrical closets in sector J span 3 floors. The analysis contrasted using bus duct, elbows, and fusible switches versus using cable and conduit.



Locations of Stacked Electrical Closets

The results from the cost analysis are as follows:

Bus Duct System					
Equipment	**Quantity**	**Price/Quantity ($)**	**Labor**	**Total Price**	**Total Price w/ Labor**
1000A Bus Duct (feet)	168	18.5	36	3108	9156
1000A Elbows	8	1000	251	8000	10008
100A Fusible Switch	50	860	121	43000	49050
600A Fusible Switch	3	5100	725	15300	17475
225A Panelboard	(-)18	245	345	(-)4410	(-)10620
400A Panelboard	(-)5	1620	1350	(-)8100	(-)14850
				56898	60219
TOTAL				**$56,898**	**$60,219**

Conduit/Cable System					
Equipment	**Quantity**	**Price/Quantity ($)**	**Labor**	**Total Price**	**Total Price w/ Labor**
#2 AWG copper cable (feet)	1018	0.475	0.408	483.55	898.894
1/0 copper cable (feet)	15	0.725	0.471	10.875	17.94
2/0 copper cable (feet)	570	0.895	0.502	510.15	796.29
250 kcmil copper cable (feet)	1121	2.16	1.63	2421.36	4248.59
350 kcmil copper cable (feet)	495	2.97	1.81	1470.15	2366.1
500 kcmil copper cable (feet)	928	4.2	2.04	3897.6	5790.72
1-1/2" EMT	1033	1.59	2.51	1642.47	4235.3
2" EMT	570	1.95	3.14	1111.5	2901.3
3" EMT	1121	3.75	4.39	4203.75	9124.94
3-1/2" EMT	990	5.17	5.02	5118.3	10088.1
4" EMT	1316	5.67	5.65	7461.72	14897.12
				28331.425	55365.294
Total				**$28,331.43**	**$55,365.29**

The cost analysis shows that the bus duct and conduit/cable systems are very similar in installation cost. Some important assumptions used in the analysis is that each panel must have its own fused disconnect switch off of the bus duct. As a result, it was assumed that that the panels would be able to be reduced to 100 amps. Also, the analysis of the bus duct only assumes material for the vertical chase of the electrical closets (it is assumed that the bus duct would receive power from the switchboard). If either of these two assumptions was unfeasible, a very significant cost would be added to the bus duct system. The advantages of the bus duct system would probably outweigh the advantages of the conduit/cable system if the school was two or more stories higher than it presently is. However, since the layout of the distribution system probably will

not change much, I have concluded that the existing conduit/cable system is a more effective system due to the overall cost.

All calculations in this electrical depth report were completed as per the guidelines of the following resources:

1. *National Electric Code 2002, National Fire Protection Agency, 2002*
2. *Electrical Systems in Buildings, Hughes, 1988*
3. *Electrical Designer's Reference Fault Current Calculator, Electrical Designer's Reference, 2003*
4. *2004 National Electrical Estimator, Tyler, 2004*
5. *R.S. Means Electrical Cost Data 21st Edition, 2002, R.S Means Company, Inc, 2002*

The following personnel were contacted for various information and statistics in the report:

1. *Karen Lascala, Consumer Relations Representative, Niagara Mohawk Power Corporation*
2. *Bob Ricci, Account Representative, Liebert Corporation Total Support Systems*