ELECTRICAL DEPTH

Electrical Depth

The entire electrical depth is based around a complete redesign of the existing electrical system which was modeled in its entirety for Technical Assignment #2. Given a tenant fit-out building, all electrical loads had to be estimated and the entire system designed around uncertainty. Technical Assignment #2 allowed for the modeling of a maximum capacity building and the comparison with the current system was a near match, if slightly oversized and undersized at some points.

This depth topic was to compare and contrast the current distribution system with a distribution system that would allow for less conductor and conduit runs, while increasing reliability. The new system would treat the building as a single-owner entity, in essence managed in it's entirety by Pentagon Management LLC. The comparison of costs will be the results and the lower cost will prevail.

Relationship with Thesis Project

Integration within the thesis is focused mainly on the Mechanical Breadth and utilizes the energy consumption information from some of the spaces in the Lighting Depth. The Electrical Depth and Mechanical Breadth are intertwined through their power distribution and generation capabilities. This is further explained in the Mechanical Breadth.

Proposal

The proposal for the Electrical Depth is to accept a single utility service pull and distribute power through the building using the Main Bus as a spinal cord from which almost all other loads are tapped. The "brain" of this system will be the Main distribution board, and the nerves will be reduced feeder lengths that don't have to span multiple floors to terminate at their associated panels. The proposal also includes the alteration of the current emergency distribution system and emergency power source. The new emergency power system will take some distinct power requirements into consideration and add an unprecedented reliability for blackouts, brownouts, building power failures, and any relative catastrophe that will eliminate power for any extended period of time.

Modeling Loads

The modeling of loads was crucial to the design of the current system and because such information was not available, had to be reconstructed based on architectural plan, and then compared with current system configurations for accuracy. Such loads that were given, including all mechanical motors loads and any electrical input requirements given in the base-building design, were injected directly into the model. The model is increased in accuracy considerably with these specifics – a secondary goal of the redesign. All loads taken from the schedules were converted from their specified horsepower or MCA requirements and converted to their kVA equivalents and/or amperage inputs.

Using NEC 2002 guidelines for approximating lighting and receptacle loads, space layouts otherwise not available for load analysis could be modeled. Such calculations are shown in the following sections.

Office

Office loads were easy to come by and were easily approximated based on the measured square footage of the office floors plans. From NEC Table 220.3(A), Unit Loads based on occupancy are given in VA per square foot, with a sub note (b) indicating that in banks and office buildings, an additional load can be added to account for general-purpose receptacles outlets. The lighting load for Office Buildings is listed at 3.5 VA per square foot with a 1 VA per square foot allowance for the receptacles. Combining the receptacle loads into a single table and calculating the Demand based on Table 220.13, adding together the lighting load and multiplying by an architectural factor accounting for the loss of usable space to partitions, etc., the final demand load for a given office floor is calculated and used in panelboard calculations. The tables used for calculation can be found in Appendix D .

As part of the office system design and to segregate the office metering panels from the house distribution, all remaining motor loads at or above the 10th floor were connected to the appropriate panels, but no house receptacles were considered "free of charge". Any and all power outlets for a given floor would be circuited to the office tenant panel and metered for consumption and billing by the building management authority, <u>not</u> the utility.

Retail

The retail loads were easier to calculate based on the approximate sizes as used by the current tenants. The lighting was approximated again from NEC at 2 VA per square foot and receptacles were calculated based on the overall demand factor for receptacles throughout the building. There was also an additional power allowance for display lighting (or "Show Windows") at 200 VA per linear foot of display window. As a demand criterion based on current tenant information, a demand factor of 3.0 was applied to all of the retail loads to account for excessive power consumption for restaurants and other electrically intensive commerce (a spa with any number of heating elements and cosmetic equipment, for further example). Tables for calculations can also be found in Appendix D .

Condominium

Condominium load modeling was much easier than either of the previous two modeling methodologies. Having experience in the dwelling unit load calculation and approximation, a very accurate model was able to be constructed and individual condominium loads based on size were calculated. Using a basic electrical appliance outline and applying the same NEC table values for dwelling units of 3 VA per square foot, a specific load calculation was made for each of the 27 units. The loadcenter calculation table along with the square footage lighting and receptacle approximation is given in Appendix D .

Distribution Configuration and Explanations

The new distribution configuration is relatively simple to understand as previously described. Supplemental to this is the riser diagram which illustrates the distribution system much better. Please refer to Appendix D for specifics regarding the distribution system. A textual analysis will describe the basic layout of the system here.

Service from a single high voltage entrance is brought in directly to the 15 kV switchgear. Voltage is reduced through the two medium voltage transformers on each end of the double ended Main switchboard. This switchboard had to be upsized to reflect the new power flow through the building to a 4000A switchboard with 4000A breakers respectively. From the main switchboard many individual loads are fed directly (namely the major heating and cooling pumps, the main retail distribution panel, the south-end high voltage parking panel (because of its remote location), the two basement high voltage panels feeding all other mechanical/electrical room loads and major motor equipment, and the basement emergency panel. The major component of the distribution system that the Main switchboard feeds is the 3200A bus duct servicing all of the above ground floors.

Alterations – Parking Garage

Major differences in the distribution systems of the parking garage include the complete rewiring of the light fixtures, and the electrical zoning of the three serving panels. Unlike the original design wherein a single panel serves half of the first 6 floors and a second serves the other half, the new design focuses on the remoteness of the southern area of the parking garage. Using the remote electrical closet, the southernmost panelboard feeds a third of the floors from basement up to the 9th (top) parking deck. This should minimize the draw of the panel feeder and branch circuits to the end loads. The remaining two panels required to provide power to the garage serve two-thirds of the lower 5 floors, and two thirds of the upper 4 floors respectively. This is not specifically modeled in the riser diagram, but can be seen in the general feeder layout in Appendix D . Additionally, the parking garage panelboards also serve the façade lighting requirements through the parking low-voltage panels. These panels serve two functions, but were initially installed to serve the 120V power supplies of the façade LED fixtures. Appropriate location of the high voltage panels and subsequent low-voltage panels was designed to specifically coincide with the zoning of the parking fixtures and the location of the LED power supplies so as to, again, minimize feeder and branch circuit draw. Because of the placement of the panels (described in detail in the condominium section) the high voltage emergency panel could also be centrally located to reduce voltage drop and help to minimize conductor runs.

Alterations – Condominium

The condominium alterations are considerable. By taking out the entire condo bus duct, distribution to each of the condominiums had to be efficient, adequate, and reduce the feeder length as much as possible. Considering the condo bus duct ran through the electrical rooms serving the condominiums, the new design used the same bus duct path and the same electrical rooms to provide distribution to the entire section of building from ground floor to 9-Mezzanine. With such a small space allocated for the electrical closet, a maximum of three electrical elements was allowed in a closet. This did mean that some feeders were routed between floors, but also meant that the available space was maximized in the same manner as the bus duct, disconnects, and meter racks were in the original design.

The bus duct rises through these electrical closets as mentioned. The second floor contains the first condominium low-voltage distribution panel which feeds the first two floors of condominiums. The fifth floor houses the second serving condos on floors 4-6 and the third is located at the eighth floor serving floors 7-9 (9 contains double height condominiums extending up to 9-Mezzanine.

These same condominium electrical closets house the high- and low voltage parking panelboards as mentioned in the previous section. They house the transformers as well. The beginning of the office alteration design starts at the 9th floor and there is nothing located at the 9-Mezzanine floor. This was not by choice, but was specifically indicated as not possible in the architectural drawings (although a waste of space, the design was intended to stay within the current guidelines and not make any exceptions). The 9th floor houses the electrical distribution panel for the condominium elevators as well as the long-draw for the parking elevators. The reasoning for not connecting the parking elevators to the remote-location parking panel was two fold – first, local law requires the elevators be placed on a standby panel with automatic transfer to emergency power when main power fails; and second, because of the power requirements and relative feeder length.

Alterations – Office

The office tower has much of the same distribution system in the new design as it had in the old design. The bus duct in the old design fed the office tenant (to be fitted out) electrical closets solely as it does in the new design. The bus duct also ran adjacent to the condo bus duct in the office design up until the 10th floor where it was diverted to the central/core electrical closet. In the new design the bus duct <u>acts</u> as the condo bus <u>and</u> diverts to the central/core electrical closet. The main difference on the upper floors of the office space is that instead of separate feeders to the house panels extending over 10 floors to their respective end uses, the feeder length are limited to the distance from closet to bus duct – or a mere 20’ maximum. This becomes especially helpful in the upper house panels (floors 13-16) where the feeder must space 0ver 130’ before reaching the nearest of the panels (or almost 200’ in the case of the house panel located at the 16th floor). Instead, such panels as the House Standby “HB” are fed directly from the bus duct, again, a no more than 20’ feeder length.

Panelboard Layouts and Assumptions

Panelboard layouts as listed in Appendix D are for both systems for their numerical comparison (and to prove that the work was actually completed). The layout of the panels is concerned with the circuiting and accurate modeling of the loads at the panelboard, and not necessarily within the panelboard. Panelboard circuiting was completed solely to illustrate which panels would be filled, which loads were three and single phase, and the routing of low-voltage panelboards through one another and, overall, into the main bus duct and main switchboard. All circuits not specifically filled by the general electrical requirements are not necessarily spaces, but instead are considered negligible in the overall distribution scheme. This assumption is valid given the base-building modeling method and oversized load parameters (proven further in the electrical load analysis in the Mechanical Breadth).

Metering and Tenant Billing

Differences in the metering of the building also exist and were a focus of the alteration in the distribution system as well. In the current system, office tenants pay a lease including all heating and electric power consumption. The property is billed for the overall building usage of power for house, standby, emergency, and office tenant panels from the office and retail service. Based on costs, the management bills the individual tenants either through a yearly cost projection average, or through monthly lease adjustments based on the average energy consumption of the office tower. The condominium tenants are individually metered and the management bills each condominium separately for their power consumption. This system requires that the management take into consideration the service voltages, the distribution costs (building-purchased transformers, etc.) and demand for each entity separately. Given the fact that there are three separate service voltages, this can be quite cumbersome.

In the new design, the proposal is to meter the office tenants individually (as seen on the riser) and meter the condominium by levels and average out the power consumption over the entire condo service section through the “Condo Association” fee. Since the house receptacles and cooling towers for the office are circuited directly to the office tenant and house panels, the building virtually sees “no power consumption” from the upper 7 floors (excluding the elevator banks, the building pressurization fans, etc). Because the offices are now billed for their separate energy consumption and altogether for their heating and hot water, management begins to see an immediate decrease in billing complexity. And considering the condominiums run from a separate heating and cooling loop, the association fee can be increased and justified to include all of the utility payments for the condominium.

The greatest advantage to this system is that the management is billed for the commercial price of electricity, steam and gas, but is allowed to charge the tenant for the residential, or secondary, price of electricity, gas and steam. With a condo association fee, the price can be maintained and fluctuations decreased simply by balancing the bills with an increased (but not immorally exorbitant) profit margin in favor of the management. More of this is detailed in the brief Construction Management Breadth.

Emergency Distribution Design and Analysis

The emergency system is the focal point of the electrical depth work. The current system allows for a maximum of 350kW of electricity to be consumed by the entire building in the case of a power failure, or other emergency where electricity is interrupted. This power consumption is limited to those panelboards connected through the automatic transfer switches to the emergency distribution panel. In the current design, this means the power is only supplied to the elevators throughout the building (but not the parking garage), and the emergency lighting throughout the building. While this can be deemed as only the necessity, it implies solely that an emergency requiring evacuation has occurred. But two things were not taken into consideration. First, all conditions where the power loss is not the result of an emergency. Second, the fact that the condominiums are residences and those people cannot simply “leave” if the power isn’t working. For this reason, the attempt was to power all vital circuits to sustain “livability” conditions in the condominiums while electrical service was not functioning.

The new system maintains power to all of the elevators just as the last system did, but also includes the elevators in the parking garage. The new system also supplies power to all of the emergency lighting – and based on the slight increase in the number of emergency panelboards, extra lighting for the condominium residences to prolong the allure of livability as long as necessary. In addition to these loads, the Evaporative Fluid Cooler and two condominium pumps are also powered to provide heating and cooling as necessary to the condominiums in the case that power is lost for greater than 12 hours in winter or summer conditions, respectively. The water source heat pumps in each of the condominium units have the ability to be connected to and emergency outlet (an outlet painted or colored red, denoting emergency power only) which received no power unless there is an emergency condition. Likewise, the same panels to which the WSHP circuits are routed to also have single receptacle circuits drawn to each of the kitchens for use in maintaining power to the refrigerator compressor. This means 54 circuits total are used for emergency conditions, fire alarm devices, single condo unit refrigerator circuits, and single condo unit WSHP circuits. (On the riser and in the panelboards these are located on panels HE / LC, HE / LC2 and HE / LC3) This added reliability prevents anyone from freezing in the winter, baking in the summer, and prevents food loss in the case of a multi-day outage. Because these condominium tenants pay their Condo Association fees, they should be entitled to a portion of the buildings emergency power backup so they can enjoy the comfort of their own home when waiting for power restoration. For all pertinent calculations and diagrams refer to the riser diagram or the panelboard schedules in Appendix D.

Cost Analysis

The cost analysis of this system's increased emergency capacity and reduced feeder and conduit draws is given in a comparison table. Each of the systems was modeled in a 3D environment to accurately measure the feeder lengths and provide a congruency to all of the similar systems and locations. This prevents fudging the numbers for or against either system and results in a very accurate comparison. The 3D models can be seen in illustrations in Appendix D or viewed in AutoCAD from the enclosed CD. The cost analysis is given below considering the current system in its entirety and the new system in its full splendor. Notice that by subtracting the new emergency requirements, a few of the new design's panels can be omitted and the generator cost would be the same, increasing the profitability of the already profitable new design. The cost comparison is given below.

Current Design	Cost	**New Design**	Cost	Difference
CONDUCTOR TOTAL	#REF!	CONDUCTOR TOTAL	$ 121,743.91	#REF!
TOTAL BUS	$ 446,295.00	TOTAL BUS	$ 447,153.00	$ (858.00)
TOTAL PANEL	$ 82,894.00	TOTAL PANEL	#REF!	#REF!
TOTAL SWITCHBOARD	$ 20,815.00	TOTAL SWITCHBOARD	$ -	$ 20,815.00
TOTAL ATS	$ 26,302.00	TOTAL ATS	$ 33,532.00	$ (7,230.00)
TOTAL MAIN	$ 6,150.00	TOTAL MAIN	$ 7,425.00	$ (1,275.00)
TOTAL XFMR	$ 206,585.00	TOTAL XFMR	$ 241,872.00	$ (35,287.00)
TOTAL GENERATOR	$ 76,550.00	TOTAL GENERATOR	$ 114,850.00	$ (38,300.00)
GRAND TOTAL	#REF!	GRAND TOTAL	#REF!	#REF!

Conclusions

The conclusion for the electrical depth redesign is simple – the redesign is better with very few reasons to the contrary. It saves money, provides a greater redundancy, can make the management company a greater profit (if just through normal billing, or the Condo Association combined fees), and could overall reduce the construction cost of the electrical systems of the building. There are a few higher initial costs for select system components, but overall is still cheaper. Because of the reduced number/lengths of conductors, and the heat gain associated with those conductors carrying current, the building might even see a marginal decrease in the buildings consumed power. And less power costs less money no matter what.