MISSION CRITICAL FACILITY DESIGN ISSUES AND LEGAL RAMIFICATIONS

Get ahead of electrical system failures before they happen.

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The design and commissioning of mission critical facilities is extremely complex. Additionally, design standards and best practices have evolved over time. It is critical that the design engineer utilize the most current best practices and design standards. The engineering firm must also understand the legal issues and ramifications that may arise out of electrical system failures. This article summarizes both the design and legal aspects of electrical system failures.

THE CRITICAL NATURE OF NEHER-MCGRATH HEATING CALCULATIONS IN MISSION CRITICAL FACILITIES

Heating calculations are recommended for mission critical facilities when large electrical duct banks with large amounts of conduits and conductors are routed in the earth. The heating calculations are performed to determine if any de-rating of the conductors is required. This de-rating is based on many factors including the following:

- Number and size of conduits and conductors
- Configuration of the conduits and conductors
- Spacing between the conduits in both the horizontal

and vertical dimensions
- Amount of earth above the conductors
- The RHO of the backfill material
- Load factor of the conductors

These calculations can be very complicated based on many of the variables noted above.

DEFINITIONS UTILIZED IN THE NEHER-MCGRATH CALCULATION

Load factor. The ratio of the average load in kilowatts supplied during a 24-hour period over the peak or maximum load in kilowatts taking place in that same period. Load factor, expressed in percent, also can be derived by multiplying the kilowatt hours (kWh) in the period by 100 and dividing by the product of the maximum demand in kW and the number of hours in the period.

Example: Load factor calculation - Load factor = kWh/hours in period/kW. Assume a 1 day billing period or 1 times 24 hours for a total of 24 hours. Assume a customer used 15,000 kWh and had a maximum demand of 1,500 kW. The customer's load factor would be 41.6% ((15,000 kWh/24 hours/1500 kW)*100). The 41.6% load factor may be representative of a standard commercial building. The load factor in a data center with fairly constant load 24 hours of the day would be significantly higher.

RHO – Thermal resistivity. Thermal resistivity, as used in the National Electrical Code annex, indicates the heat transfer capability through a substance in the trench by conduction. This value is the reciprocal of thermal conductivity and is typically expressed in the units C-cm/watt.

Where an underground electrical duct bank installation utilizes the configurations identified in the National Electrical Code (NEC) examples, the NEC indicates in section 310-15 (b) that calculations can be accomplished to determine actual rating of the conductors. A formula provided in the NEC can be utilized under "Engineering Supervision" to provide these calculations. This formula is typically not sufficient because it does not include the effect of mutual heating between cables from other duct banks.

For distinctive duct bank configurations, an electrical system design engineer should utilize the Neher- McGrath calculation method. These calculations are very complex and involve many calculations and equations, and can be exceedingly time consuming. In addition, many of the calculations build on each other, so an error in one part of the calculation can result in a significant error in the final outcome. The hand calculations become even more complex if cable in the duct bank is of different sizes.

The effects of mutual heating from adjacent conductors and feeders serving different types of loads with varying levels of load factor can significantly increase the complexity of the calculations. Additionally, all failure modes of the mission critical facility must be evaluated. Figures 1 and 2 are two examples of mutual heating calculations with server loads (UPS) in the 88% to 95% load factor and mechanical loads in 30% to 65% load factor range.

It must be noted that these calculations are examples only and that specific evaluation of the server loads and mechanical loads in the mission critical facility must be independently evaluated.

If the intent is to utilize native backfill, soil samples, and dryout curves, testing per IEEE-442 are required to

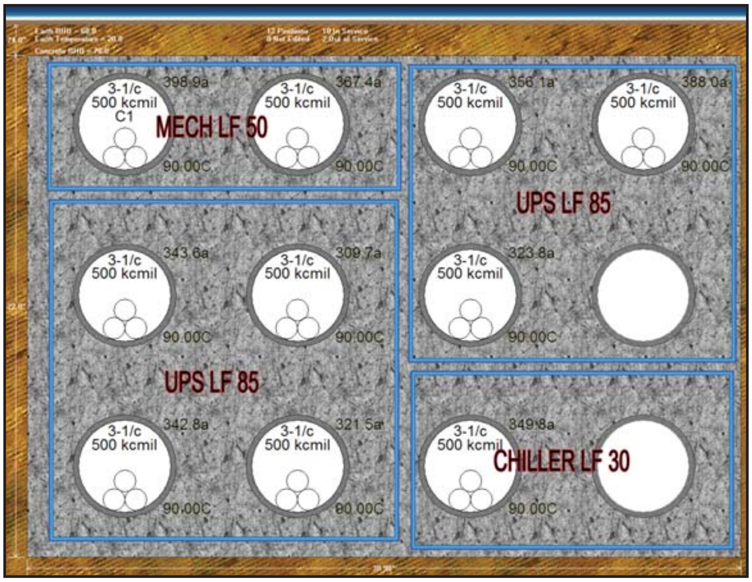

Figure 1. Illustrates a typical electrical ductbank with UPS (critical) feeders as well as chiller and mechanical feeders in the same trench. This figure also illustrates the complexity of mutual heating from adjacent sets of conductors that have various levels of load factor. All variables including ductbank configuration, system loading, failure mode analysis and the load factor of the various feeders must be determined prior to final calculations.

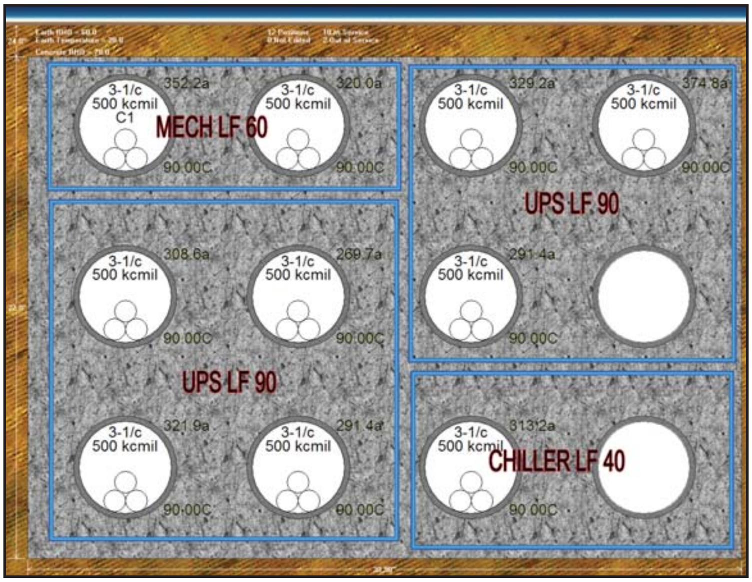

Figure 2. Additionally illustrates that at higher load factors for UPS (critical), chiller and mechanical feeders, the maximum capacity of the feeders is reduced.

evaluate the actual value of RHO to utilize in the calculations. The average RHO values listed in the NEC have been utilized in the past, but should not be used for site specific calculations because it has been our experience that there is no average soil. An evaluation of worst case moisture content must also be provided. If the engineer has utilized values that are too low and do not represent the actual value, overheating, thermal runaway, and failure can occur. If the engineer utilizes overly conservative values, too many conduits will be utilized; resulting in more cost, space, and higher fault current levels.

Insufficient and/or uneven compaction can greatly increase RHO values in the areas not compacted correctly. Hot spots in the underground conduit can lead to thermal instability and thermal runaway.

If native backfill is utilized, compaction must be performed in layers and compacted to 95% of original compaction or as specified by a soils engineer. Some times 95% is not possible. If not compacted properly, there will be more air pockets and the actual RHO values will increase. We have seen installations with four layers of conduits, in these cases the contractor would require some kind of liquefied fill to get proper compaction (concrete or engineered backfill). All of these materials could provide for proper compaction and all can have significantly different levels of RHO. All liquefied fills and/or slurries must be tested per IEEE-442 for RHO value prior to installation.

Increased water content helps provide for better heat conduction via thermal bridges, therefore the thermal resistivity is typically lower in damp soil. In dry soils there are discontinuities in the heat conduction path due to lower water content. In these cases soil thermal resistivity (RHO) increases. In poorly compacted soils, air gaps can develop in dry soils that can greatly increase the RHO values. Sometimes these increased RHO values can be higher than those shown for 0% moisture in the soils dryout curves.

The contractor must also be careful in areas where they are utilizing a slurry and transition back to native backfill. Even if the conduits with native backfill would have been installed in layers and compacted in lifts, there would be an area in the transition between native and the slurry of several feet that could not have been compacted correctly (Figure 3).

For soil to compact correctly it must compact against a fixed object or the earth. When soil is compacted with no back pressure the soil will deform and not compact correctly.

In addition, accepted building standard are to provide 6-in. lifts.

Providing less than 6-in. lifts presents the following issues:

- Greater potential for damaging conduit.
- Inability to attain proper compaction (Figure 4).

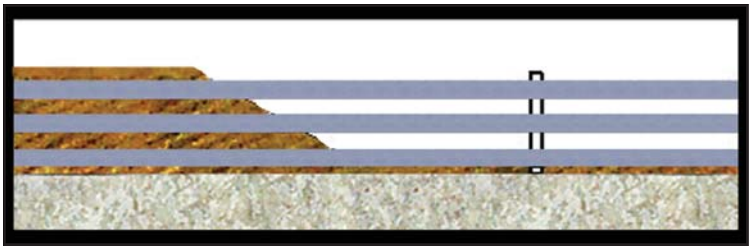

Figure 3. Illustrates a transition area between native soils and a slurry.

Figure 4. Illustrates the pressure applied to the native backfill area and the deformation that can occur in the transition area between native backfill and a slurry. In this transition area, proper compaction is difficult if not impossible to achieve. Without proper compaction the RHO values in these transition areas can be greatly increase, potentially causing overheating of the electrical conductors.

LEGAL CLAIMS THAT CAN BE MADE AFTER MISSION CRITICAL PROJECT FAILURES

If the design or construction of a mission critical project is incorrectly or negligently performed, then the project can be at risk of overheating or failure. As discussed above, an engineer's failure to account for the heating effects of the soils or other backfill materials, or the contractor's failure to properly compact the soils around the electrical conduits, among many other causes, can lead to overheating and system failures. These failures can also lead to litigation and lawsuits.

When a mission critical facility fails, the initial reaction of the property owner will be to blame anybody and everybody involved in the design and construction of the system, and to seek monetary damages from the entities that played any role in causing the alleged failure. To determine the cause of the overheating or failure, and to determine a possible scope of repair, the owner will likely hire consultants to analyze the failed system. The consultants will typically apply modern day design standards and techniques to their failure analysis, which may result in conclusions showing that the original design and/or construction was defective. The results may also lead the owner to conclude that its system will require significant repairs and upgrades. Notably, these "cause" and "repair" conclusions are radically different from a determination of whether an engineer breached its design contract or was negligent, and if so, what damages the engineer may be legally responsible for.

Specifically, for an engineer, a consultant's analysis based on modern day standards will not prove that the engineer's design work was negligent, or that the engineer breached its duty of care. In order for an owner to prove that an engineer breached its contract, or that it negligently performed its design work, the owner must prove one critical issue — that the engineer breached its duty of care that was applicable at the time the design work was performed.

In most jurisdictions, and under most contractual agreements, engineers and architects are required to perform their services with the same degree of skill and professionalism that is required of similarly-situated professional designers, under similar circumstances, in the same locality. An architect and engineer's designs are not required to be 100% perfect, but they must comply with the industry standard of care applicable at the time the design work was completed. This is critical. So critical, that we will say it again: the designer's work is only required to comply with the standards of care applicable at the time the work was performed. The designer is not required to perform its work in accordance with heightened standards that may develop over time and that may become applicable at a later date.

This is particularly important with the design of mission-critical projects. Design standards for mission critical projects were developing in late 1990 and early 2000, and have changed dramatically over the past 10 to 15 years, especially as related to how and when Neher-McGrath heating calculations need to be performed. The knowledge that engineers use to design mission critical projects, and the electrical systems to support these projects, has grown exponentially over the years. As such, the standard of care that was applicable in late-1990 and early-2000 is vastly different from the standard of care that is applicable today.

Since industry standards have changed so dramatically overtime, the use of modern day standards to analyze an underground duct bank failure in a mission critical project does not provide definite support for legal claims against the engineer. In order to determine whether an engineer complied with its standard of care, the parties' failure analysis must be based on the standard of care that was applicable at the time of the design. While this may seem obvious on its face, this analysis becomes difficult to perform, especially when the owner is anxious to remediate its property under the currently applicable design standards.

Essentially, two separate analyses must be done — one analysis applying current day standards to determine the cause of the failure and the proposed scope of repairs; and a second analysis applying the original design standard of care to determine whether the design was adequate and to determine legal damages. The results from the second analysis will provide support for legal claims against an engineer.

Determining the cause of the failure is not the same as determining whether an engineer is legally liable, in negligence or contract, for the overheating incident. Determining the cause will typically utilize modern day knowledge. Therefore, the results of that analysis will not answer the critical question of whether the engineer failed to comply with the applicable standards at the time of the design. In other words, even if the design caused the overheating failure, it does not mean that the engineer was negligent or breached the standard of care. This legal liability question can only be answered by determining whether the engineer breached the standards that were applicable at the time of the design.

Similarly, the scope of repair is not the same as an appropriate scope of legal damages because, again, repairs and legal damages are based on different analyses. Repair analyses typically use modern standards to determine an appropriate fix based on the most up-to-date industry knowledge. Because repair analyses apply modern day standards, the repairs might include a significant amount of betterment, and that the system will be improved overall. In effect, the system under the new design benefits from the years of increased knowledge and information gained by the industry. While an owner may choose to complete repairs based on modern standards, it does not mean that a designer will be legally responsible for that betterment. In fact, most jurisdictions expressly prevent an owner from collecting money to pay for its repairs that make its system better than the original design.

As an example, this idea applies to the development and importance of Neher-McGrath calculations over the past 10+ years. In the late 1990s and early 2000'\s, many engineers were just starting to consider whether, and to what extent, Neher-McGrath calculations were needed to determine whether a data center electrical system under 2,000 V needed to be de-rated. The standard for many engineers at the time, especially for low-voltage systems, was that engineers were not required to complete the calculations. And, even if the engineer completed the calculations, the industry-standard was to use RHO values provided by the National Electric Code. The applicable standard did not require engineers to determine the actual RHO value of the soils or concrete materials that were used to backfill the underground electrical duct banks. Therefore, by way of example, if an engineer designed a data center in 2000 and did not perform Neher-McGrath calculations or backfill RHO testing, its failure to do so does not automatically prove that the engineer breached its duty of care. Instead, to prove that the engineer breached its duty of care, the failure analysis must determine whether the design failed to perform under the industry-standard requirements in 2000. Applying modern day standards to an old design will lead to false conclusions on whether the system failed because of an alleged design defect, and will lead to excessive scope of repair.

WHAT CAN ENGINEERS DO TO PROTECT THEMSELVES FROM LIABILITY CLAIMS?

Unfortunately, there is no foolproof way that engineers can protect themselves from legal claims that may arise out of their earlier mission critical projects. However, there is one measure that a designer can employ to protect himself on future projects. The designer should ensure that all contracts specifically state that the design work must only comply with the applicable standard of care at the time. This type of contract provision will provide the designer with an ongoing level of protection in an industry that is quickly advancing.

Designers can also defend against possible future claims by remembering that their old design work was only required to meet the applicable standards of care — not the current day standards. Applying current day standards will lead to incorrect and unnecessary liability exposure. ■

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