Properly Sizing the Electrical Service for a Refrigerated Facility

Published by the Controlled Environment Building Association

CEBA
Controlled Environment Building Association

A Core Partner of
GLOBAL COLD CHAIN ALLIANCE®

January 2023

Acknowledgements

The *Electric Design Task Force* worked on drafting and publishing in 2023 and whose members were:

Michael Adkins, BentallGreenOak

Josh Currie, NewCold Advanced Cold Logistics

Curt Edmisten, MTC Logistics

Kurt Liebendorfer, Evapco Inc.

Jim Romine, Lineage Logistics

Thanks to Kelly Waterman, KWR LLC for the technical review.

With Special Thanks for review and guidance to The GCCA–CEBA Construction Codes Committee

Disclaimer. This paper discusses considerations that can be discussed with your electrical engineer to help in sizing your main switchboard and design the of the electrical room for your facility. This is not an attempt to tell you how to design the system and this does not replace the need for an electrical engineer to design your electrical system and future needs.

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Introduction

When designing the electrical system for a refrigerated facility, there is an opportunity, whether intentional or unintentional, for the service transformer and the main switchboard to be sized significantly larger than needed for the application. This is due to several factors, such as safety factors, future expansion, total connected load, and local code influence, among others. Sometimes, this can lead to an oversized main switchboard and add unnecessary cost to the project. This problem worsens when there is no room or reason for future expansion of the facility. This paper discusses the influences on the design size of the electrical main and the mitigating factors that can be considered when sizing the main switchboard on a new refrigerated facility.

Additionally, as this paper was being developed, we found other areas of the electrical system that needed to be discussed to provide proper context for the electrical system sizing topic. This led us to develop a more holistic discussion of the facility's electrical service and provides an overview of additional considerations for the facility's electrical system. These additional topics cover primary versus secondary metering, electrical systems including automation and refrigeration, backup generation, and other items.

Power from the Utility or Service Provider

Typical power plants generate electricity in the range of 1,000 – 2,000 megawatts or more, while a cold storage warehouse can often consume 1 – 3 megawatts of power. The power needed to operate the facility is transmitted from the power plant through an electrical network of transformers, substations, and power lines to deliver high-voltage electricity to the facility's site. The high-voltage power from the transmission network is connected to the facility via a transformer(s), which decreases the power of the network to a lower voltage at 480Y/277V, 3-phase, or similar be utilized by equipment onsite. The design of the onsite electrical equipment, including the transformers, depends on several mitigating factors. These mitigating factors can impact the upfront cost of constructing the facility and the operation of the facility's electrical system.

There are typically two types of service that can be secured from the power provider, primary metered or secondary metered service. Primary service is a higher voltage service that the power companies use to distribute power more efficiently across long distances. In industrial uses, the primary voltage that the power company provides is typically around 12,000 volts or higher. Secondary service is a comparatively lower voltage service that the power company offers after stepping it down through a transformer. This power is brought to the facility at a primary voltage where it then is transformed to typically 480-volt service.

The difference to consider is where the facility takes ownership of the infrastructure and the cost of the power. In primary voltage service, the power company provides and meters power to the property at the primary voltage, and the facility is responsible for purchasing and installing the transformer(s) and bringing the power to the transformers. When choosing secondary power as the provided scope, the power company offers the transformer(s) and infrastructure to supply them with power and then meters the power consumed after the transformer. The difference in cost for the power company to provide and own the transformers is built into the power rate.

Additional considerations for primary metered power are the cost and risk of owning the transformer(s). Transformers must be maintained, and testing is required as part of ownership. There is also the risk of failure of the transformer(s), and the cost of repair or replacement can be considerable, along with downtime for securing a replacement. The utility may also ask you to provide and maintain the on-site high-voltage switchgear.

When deciding whether to secure primary or secondary power, the initial cost and ongoing cost of owning the primary infrastructure, along with any risk, has to be balanced against the cost savings for primary metered power over time.

Benefits to Diversity in Electrical Load Design

In each facility, electricity powers equipment, and the electrical load is the sum of all the energy consumed at a facility. Electrical load calculations determine the size of the transformer a facility will need and the monthly service cost from an energy provider. A larger transformer will have additional upfront costs. Each type of service also has different rates. Overestimating load could lead to additional upfront construction costs and higher energy bill rates. Underestimating load could result in not enough power being delivered to the site.

Diversity in Utility Service Sizing

Diversity is often recognized by utility companies in the sizing of their primary transformers because the building is typically designed in accordance with the National Electric Code (NEC), which has a connected load based on the full rating of the equipment, whereas in reality all of the equipment is rarely operating full load simultaneously. Most utility companies recognize this approach in their utility sizing for both circuits and transformers. As an example, the connected load may indicate that a 3000kva transformer may be required to accommodate the design. However, in reality, the typical peak demand could be less than 50% of your connected load if the guidance in this paper is not considered. Utility companies recognize this and transformer/circuit sizing can be reduced or ‘diversified’ to match actual load demands better. The same principle can be applied in designing the building's electrical service.

There are two types of electrical loads: connected and running or demand loads. The connected load is the sum of all the nameplate ratings of the related equipment in the electrical system. Everything that is plugged in or hard-wired is part of the connected load. The equipment is "connected" to the electrical system via wires and plugs. Connected load is the sum of all energy consumed if everything runs simultaneously at full capacity. Only utilizing the connected load to evaluate a facility's power needs will result in an oversized transformer and likely higher power rates for the facility's life.

Sections NEC 220.60 for non-coincidental loads and NEC 430.26 for duty-cycle or intermittent operation considerations may allow for this consideration in the design of industrial facilities, provided good historical records are maintained for similar facilities to demonstrate actual peak demand vs. connected design loads. The design, per the NEC, may require that your connected load is 12,000 amps at 480v. On the other hand, the actual peak usage at the facility could be at 50 percent, so conservatively, three 4,000A Services could be reduced to two 4,000A services eliminating one switchboard while still maintaining excess capacity.

The Authority Having Junction (AJH) may grant permission to allow a demand factor of less than 100% if operational procedures, production demands, or the nature of the work is such that not all the motors are running at one time. Engineering study or knowledge of engine operating characteristics within a facility or on multi-motor machinery may provide information that allows a demand factor of less than 100%.

Running or demand load is the total electrical consumed at a facility during typical operations. For example, while a facility may have hundreds of pieces of equipment connected to its electrical system, not all equipment will run simultaneously. Only the powered operating equipment will create demand, and only equipment running at full capacity will equal the total energy on the equipment's nameplate.

Electrical Service for Refrigeration Equipment

Typically half or more of the power needed for the cold storage facility is the refrigeration equipment. The refrigeration equipment and systems that serve the cooling loads are sized and designed for the peak cooling load, which most often occurs during peak summer ambient temperatures and/or peak product loading conditions. This peak condition typically only occurs for a small portion of time annually, and the system runs at a partial load condition for the balance of the time. As a result, refrigeration electrical usage typically has a large diversity factor. Understanding or identifying the expected load profile may be beneficial in defining the corresponding electrical demand profile.

Identify what installed refrigeration equipment is required to run to meet the peak load versus other refrigeration equipment that is not needed to run simultaneously. Because it is designed as backup, spare, or swing machine, it is essential to define to not oversize the electrical service.

When sizing the electrical service, the electrical design engineer needs electrical ratings for the refrigeration equipment, including FLA, MCA & MOCP values provided by the equipment suppliers. These values are defined as follows:

- FLA (Full Load Ampere) is the continuous current that equipment or machines can draw in running conditions at maximum load. FLA is used for electrical load calculations and sizing over current protection in circuits.
- MCA (Minimum Current Ampacity) is the minimum current rating for the supply wire or conductor.

- MOCP (Maximum Over-Current Protection) is the maximum permissible rating or size of the circuit breaker.

FLA and MOCP values help illustrate the difference between running and connected loads, where the latter is always greater by design. Note that having equipment that is oversized well above what is needed to satisfy the running cooling loads will result in this becoming more of an impact on oversized electrical service, particularly if the connected loads are added together in the sizing of the electrical service.

Refrigeration is one of the critical systems in a cold storage facility and is typically designed with backup or redundant equipment that can be put in service when primary equipment needs to be serviced or has a failure. Some of this equipment can have a sizeable electrical load with backup compressors that have large motors. While this backup equipment is not designed to run at the same time as the primary equipment, care should be given to insure it is not inadvertently added to the run list and started while the primary equipment is online. Other systems that have backup equipment should also be evaluated to ensure the backup equipment is not put in service with the primary equipment.

There is also the potential for major system components to start up automatically at the same time causing the electrical system capacity to be exceeded. This could happen in the event of a power failure when service is restored if all equipment restarts at the same time. Care should be given to sequence the restart of systems to avoid this problem.

Additionally, the high inrush current for larger motors used in the refrigeration system can be problematic in certain cases. This can be somewhat mitigated if it is a problem by the use of VFD's to limit the inrush current during start-up. Other means to accomplish this can be employed such as equipment or system capacity controls and automated management of operating conditions.

Diversity in Building Load Sizing

Cold storage construction is often a phased approach. Master plans should include electrical details showing the current and future planned construction. Planning for the future electrical equipment load will help make the best business decision between upfront capital, energy rates, and future cost avoidance. The connected, peak, and diversity factor calculations will change for each phase, resulting in potentially different energy rates and equipment needs. Master planning for transformers and electrical switchboards may impact the transformer and electrical room location. For example, installing all electrical equipment on the far end of a warehouse near a engine room may make sense for refrigeration equipment. Still, it may not make sense for future automation equipment planned for the opposite side of the warehouse. Not planning for this load could result in oversized transformers and switch panels near the engine room or impact cost with thousands of feet of electrical wire run down the dock to power the future equipment.

When operating a cold storage or automated cold storage facility there are many components sensitive to continuous operation. Furthermore, most facilities will have multiple main switchboards fed by individual utility transformers. These can include but are certainly not limited to refrigeration systems, IT & data systems, alarm and security systems, WMS, etc.. Attention should be paid to how these loads are designed into the system in that you may not want to put all your refrigeration equipment on one switchboard or all IT infrastructure on another. Redundancy is important to mitigate operational stoppages.

Gaining Approval of Diversified Load Calculations

In recent years, we have seen some positive results applying this approach to cold storage and or automated cold storage facilities. In some cases, it requires a variance and in other cases, it can be accommodated through the normal permitting process. It is a recommended good practice to reach out to both your power utility company and the AHJ to determine and define potential paths to capitalizing on diversity or the application of demand factors in the electrical design. Further, it is also a recommended good practice to have the ability to meter, monitor, and log all power data related to facility consumption. This can be done for each breaker within the main switchboard and or with external power metering, however the prior is this most economical and reliable approach. All major switchboard and breaker manufacturers offer metering options.

Consider two identical cold storage warehouses built across the street from each other. These warehouses will have equal connected loads. Theoretically, these warehouses could have matching energy usage. However, this will not be the case. Diversity of operations in identical facilities results in different energy usage. The different manner and use of the individual connected equipment will impact the energy required to operate each facility. The expected diversity in operating loads can be evaluated as well as other influences during the design phase of the project including:

- Electrical Engineer/Designer – discussions need to take place with the Electrical Engineers to incorporate the best approach and design of the electrical system and how it can influence the sizing main service, transformers, and switchboards as outlined in this paper. A person knowledgeable in the refrigeration system design and operation, and other major electrical users such as Automation Systems, should also be consulted
- Code Officials – discussions need to take place with the AHJ code officials to determine how they could influence the electrical system sizing.
- Backup or Redundant Equipment Loads - Discuss any backup or redundant electrical loads that that will only operate when other equipment is not operating.
- Future Expansion – discuss the potential for future expansions that would contribute to the electrical load.
- Safety Factor – discuss how safety factor is required and also can be added above what is required.

Related Considerations

Automation systems

Automation systems and thereby corresponding power needs can vary dramatically depending on the scope of the automated systems. Therefore, it is strongly recommended that an Integrator and or Material Handling Equipment (MHE) specialist in collaboration with your electrical engineer are part of the early design process. Most automated facilities are sized and designed around the automation systems within in which case the applicable specialists are on board very early in the process and should be able to provide guidance on early assumptions until such time all loads can be validated.

A fully or highly automated facility managing 100,000 pallet positions more or less can require a higher-than-average electrical load whereas a partially automated facility can have extremely limited loads. While this document is not intended to prescribe load calculations, t is expected to see a significantly higher demand for a larger fully automated facility.

If equipment selection is not possible at time of design commencement it is recommended that placeholders be determined with your integrator and or MHE supplier. The following are some examples of equipment which should be considered:

- Direct circuits for crane and crane controls
- Pallet Elevators
- Pallet Wrappers
- T_Cars, Shuttles and or Monorails
- Compressed Air Systems
- Conveyance
- Air Systems
- Airlock or pass-through doors
- Maintenance Receptacles and Welding Outlets

For fully and or largely automated facilities, most conveyance systems are fed via MHE Control Cabinets located within or adjacent to the primary electrical room. These are generally fed from main switchboards with MHE power distribution from these control cabinets. However, not all equipment is fed from these cabinets with direct connection from house electrical system required at times. For example, cranes, elevators and pallet wrappers typically require direct feeders from the house electrical system whereas conveyor motors and controls would feed from the MHE Control Cabinets. There are many components that make up an automated system and it can be very easy to underestimate demand if an integrator or MHE specialist is not part of the initial design team and effort.

Diversity within MHE systems can be challenging to determine given the continuous and concurrent operation of these systems. However, power monitoring and logging can provide valuable usage data which can be used to validate diversity reductions on future facilities of similar size and design.

Power quality and reliability are essential to maintaining automation systems. Harmonics and power factor issues can have significant negative impacts to power reliability and functionality of automated systems.

Appropriate grounding of power distribution for MHE systems shall also be considered as unintentional ground faults can disrupt system operation.

With most MHE Equipment being manufactured abroad, attention shall be paid to assure that UL Listing are provided for all motors and electrical assemblies and that all voltage conversions are accounted for in electrical design and load calculations.

Backup Generation

Another consideration when designing the electrical system is the need for backup generation. Backup generation can be implemented in a variety of ways and options. The intent is to provide a power source for critical items and processes in the event the power company incurs a power outage for an extended period of time.

Many times, life safety systems are powered by a small onsite backup generator and or lighting inverters that eliminate the need for individual battery-powered fixtures. This is incorporated to provide power to the critical lighting and other systems that are needed in a power outage. To power larger systems such as refrigeration, automation, battery charging, etc., that have significant electrical loads, large backup generation needs to be considered. These loads can range from 250 KW to 2 MW and above.

Several considerations need to be made when evaluating the need for backup power generation:

- Risk and severity of an outage – Are the facility located in an area that experiences power outages or has an increased risk of extended outages? An example would be some coastal areas that are at risk of hurricanes.
- Mission critical power needs – Are systems in the facility critical to operating in case of an extended power outage, such as refrigeration and/or automation systems?
- Duration of outages – Can the facility sustain a relatively short outage duration, or is it critical that operations continue no matter the duration of the outage?

Evaluating the above considerations will help you determine the need for onsite backup power generation or if portable generation is appropriate for the facility. You will also need to understand loads of the systems you plan to power with backup generation to guide you to the generator size needed.

Two options for backup generation are on-site or portable. Onsite generation is when a generator is installed on-site and is typically tied into an Automatic Transfer Switch (ATS) that will engage the generator for power when a power loss from the utility occurs.
The other option for backup generation is a portable unit that is brought on-site during an outage and is connected to the main switchgear through a Manual Transfer Switch (MTS) to provide power during a utility outage. In this case, some means of connecting the generator should be made on the exterior of the building.

For both options, there needs to be a consideration in the electrical system to provide for disconnect from the utility and switch over to the generator power. This is done through either an ATS or an MTS. Both transfer switches should provide positive disconnection from the utility so backup generation can be engaged. This is required by NEC code and utility companies to ensure that the onsite standby generation is not allowed to 'back feed' the utility grid and put utility workers at risk.

One additional consideration for both types of generation is to make sure there is a reliable fuel source for the generator. If diesel generators are used, you should understand the fuel consumption and arrange with a fuel provider to provide fuel as needed to ensure operation.

Regardless of the generation type and expected duration interface with the generator, it is critical to evaluate the needs and types of generation when planning the electrical system design to incorporate the backup power interface into the system.