EGRESS ACCOMMODATION FOR FACTORY ASSEMBLED STRUCTURES REVISION JAN 2025

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Abstract – The *National Electrical Code (NEC)* is periodically revised to enhance efficiency, account for technology development, and to improve standard safety practices. Recent code changes made in the 2023 Edition significantly impact various industries, particularly regarding the use of prefabricated structures in brownfield applications. One key amendment is the egress requirement added to sections 110.26 and 110.33 for equipment under & over 1000V. This code requirement is to be treated independently from working clearance and specifically necessitates that 24 inches of egress are made available in all aisles while equipment doors are concurrently open. The implication is that buildings will be designed with larger footprints, additional shipping splits, and will likely become more expensive to construct. Engineers must adapt to provide innovative design methodologies to meet these demands. This paper reviews the egress code requirements, impacts to industries, and some of the devised strategies to meet standards and promote a safer electrical infrastructure.

Index Terms: DCS-Distributed Control System, MCC-Motor Control Center, PDC-Power Distribution Center, RIE-Remote Instrumentation & Electrical Building

I. INTRODUCTION

In April of 2024 Washington State Adopted the 2023 edition of the *NEC*. Among the code changes in the NEC is a requirement to accommodate egress in addition to the traditional working clearances. This requirement has been added to both sections *110.26 Spaces About Electrical Equipment* and *110.33 Entrance to Enclosures and Access to Working Space* and applies to equipment above and below 1000V.

The code change reads "Open equipment doors shall not impede access to and egress from the working space. Access or egress is impeded if one or more simultaneously opened equipment doors restrict working space access to be less than 610 mm (24in.) wide and 2.0 m (6 ½ ft) high.".

The added egress requirement with simultaneously opened doors greatly increases the minimum space requirements in building design and will impact industrial facilities capability to use their often-limited real estate effectively. It is important to recognize that the design of all projects is to: (1) maximize safety for personnel; and (2), provide value engineering solutions for all applications.

One of the greatest advantages in using factory assembled structures is the reduction of effort required in the field. Accommodating increased egress distances will likely require larger or additional shipping sections. Overall, this impacts the cost for engineering effort, shipping coordination, and field construction support and re-assembly. While building manufacturers can provide as many shipping sections as needed, the available footprint for installing a building and additional cost constrain the feasibility of future projects, including those that may be critical safety improvements for industrial processes.

This paper will begin by proposing updated code language related to Switchgear and Motor Control Centers with justification for the suggested change. A case study for a Remote Instrument & Electrical building will be presented, highlighting the impacts of the code change. The paper will conclude with a discussion on mitigation strategies and PDC design considerations including some indication of the impact on cost.

Figure 1 Example Switchgear Lineup

II. CODE CHANGE PROPOSAL

A. Code Exemption Addition for Sections 110.26 & 110.33

> "Facilities with restricted access to qualified persons working in normally unoccupied spaces, with documented training in over 1000-volt ac or 1500-volt dc systems may consider the egress measurement for switchgear and motor control centers as a single section fully extended with an additional 24 inches (working clearances still apply) provided the following requirements are met:
>
> A. A minimum of two paths of egress must be available from any location in a working space.
>
> B. Equipment across aisles may not be racked out simultaneously such that egress is impeded. Equipment immediately across an aisle cannot be racked out at the same time unless 24in is available while fully extended."

B) *Justification*

Power Distribution Centers (PDC), Motor Control Centers (MCC) and Remote Instrument & Electrical (RIE) buildings at industrial facilities are often unoccupied spaces and the only people entering these spaces are the approved onsite technicians that are trained on the site industrial practices as well as the equipment being serviced. Industrial facilities have established detailed safety practices, lock-out tag-out (LOTO) procedures and conduct regular training to prevent incidents.

As Electric Utilities can benefit from an exemption from the NEC (Article 90.2), private companies do not benefit from the same. However, these private enterprises that own and operate power distribution infrastructure are in essence acting as their own utility within their premises. As such, they should follow design and safety rules of similar standards as public utilities, provided that they maintain restricted access and a documented record of personnel training.

While cost mitigation strategies can be implemented to accommodate egress for doors that hinge, little can be done to address switchgear and the cost that comes with designing factory assembled structures with significantly larger aisles. Arc Resistant and UL listed equipment doors such as those on switchgear cannot be easily changed. Specialized hinges complicate the implementation of wire harnesses for switchgear as well. A 180° door swing would also block or interfere with door mounted equipment in such a case.

Many of the infrastructure upgrades that require these spaces in industrial facilities today are to improve process and environmental safety. It is important to work with existing technology and make practical use of the available real estate in brownfield designs so infrastructure upgrades can continue.

This exemption requires that multiple routes of egress be made available in the space and ensures safe working conditions for personnel to conduct maintenance. The exemption also serves to provide clear guidance to local inspectors & AHJs for the intent of the code.

III. CASE STUDY

The following is a case study for an instrumentation and electrical building to be installed in a refinery unit. The building was designed to maximize the footprint within the site constraints, while not requiring any shipping splits (45ft L x 13ft W x 13ft 9in H). The building is purged and pressurized for a Class 1 Div 2 groups C and D hazardous areas using a dual 6-ton HVAC system. Several exterior lights, various fixtures, and external HVAC system are to be shipped loose and installed on site.

This RIE building is situated near the hazardous area boundary of a building to its south and is bordered by fin fans to the north, a switch rack to the east, and constrained by a rail system to the west where equipment is periodically lifted out by cranes for maintenance.

The planned unit tie-in points consist of large duct banks and cable tray (Figures 2 & 3) to cutover all the existing instrumentation in the unit and provide capacity for additional safety improvement projects. The planned installation is situated near a high traffic area where crane lift locations are common, limiting the available footprint. Additional height complicates crane activity in the area; therefore, all duct bank stub-ups must be external as bottom entry would require an elevated structure.

The building interior consists of 13 marshalling cabinets that line the north and south walls with a central row of ten assorted Distributed Control (DC) and Safety Instrumented System (SIS) cabinets. The east wall will have three distribution panels (one house power and two UPS power). The west wall is entirely occupied by the HVAC system.

A common historical design for a building of this nature would include 3ft 9in. of clearance between cabinets across an aisle. Typically, this was enough for a single equipment door (~3ft) to be opened and still provide room for personnel movement through the area as long as the directly opposite equipment door remained closed. Previously, the NEC working clearances governed the minimum separation between cabinets across an aisle. The new addition differentiates egress from working clearance and adds additional consideration for design.

Interpretation and state adoption of the NEC is up to local AHJs. If the AHJ interprets the new egress requirement to be edges of both doors across an aisle at 90° plus 24-inches, the new aisles could be as large as 8ft (assuming a pair of 3ft doors on cabinets facing each other).

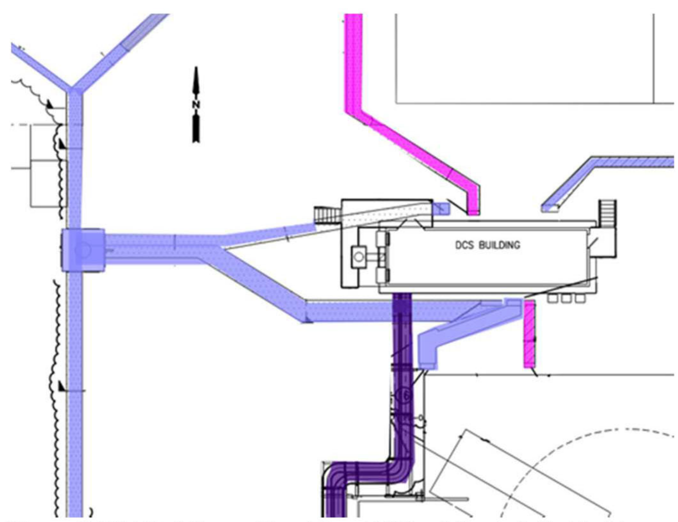

Figure 2 RIE Building – Plan View W/ Duct Bank & Cable Tray

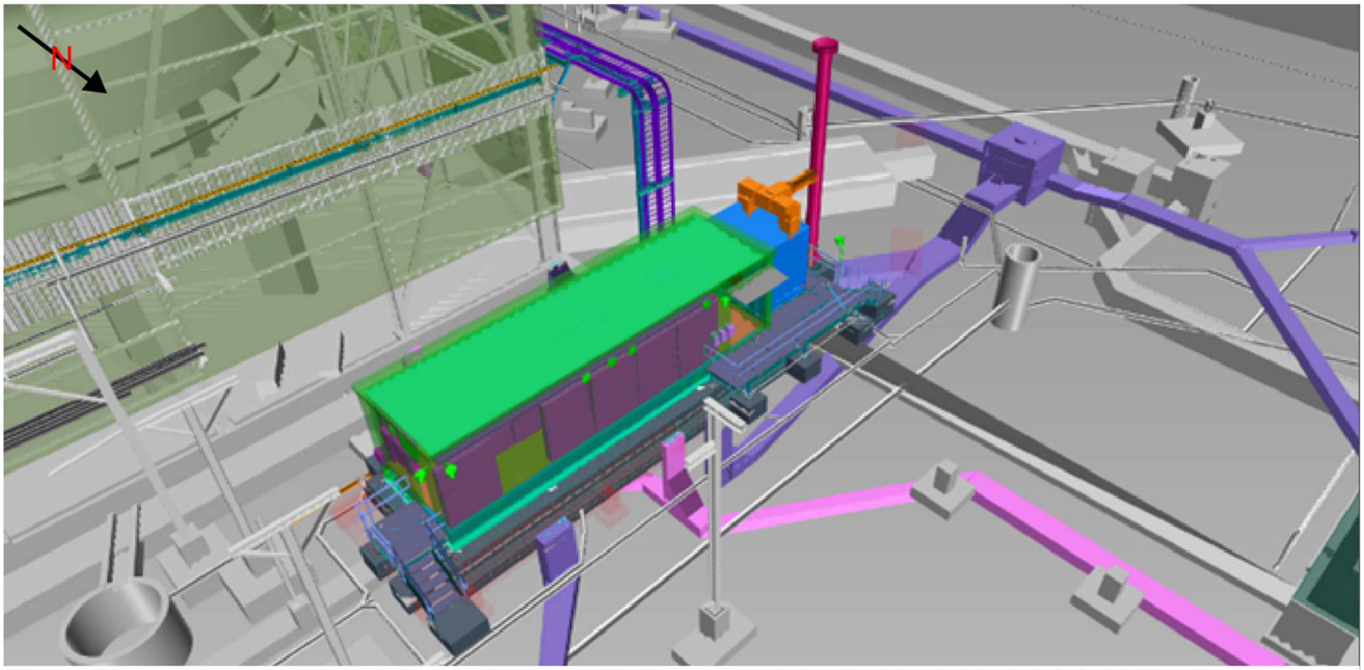

Figure 3 RIE Building - Model View W/ Power Duct Bank (Pink), Instrumentation Duct Bank (Purple), & Cable Tray (Purple)

A local AHJ thus far interprets edges of doors at maximum open angle can be measured for 24-inches of egress. This is only if the doors do not latch. Latching doors will be measured from where they lock out.

Some AHJ's may require additional egress plans for approval. These plans may include depictions of working clearances, voltages present inside cabinets, angles of door swings and a clear path for 24-inches of egress throughout the space.

In this case, an estimated material change order to expand the building would be $130k. This would require duct bank modification for bottom entry, ultimately raising the building and obstructing critical crane operations. Raising the building would also add significant engineering, field labor and cost (~$470k).

An alternative solution was to have the marshalling cabinets modified to incorporate hospital hinges (~$1,800/ea.) to allow for 180° door swing, saving an additional six feet of building width.

There are a number of options for having cabinets modified. In this case the cabinet manufacturer agreed to modify their cabinets to the engineer specifications. This is likely the cleanest route with lower labor cost. If the manufacturer is reluctant to modify their equipment, many fabrication shops are ready and willing to work out a solution that works for the project.

Figure 3 illustrates an approved egress plan. The marshalling cabinets along the exterior walls are shown to open 180°, and the DCS cabinets down the center show their maximum opening angle of 150° Working clearance is shown in blue and 24-inches of egress is shown in grey down each walkway and out the exits.

By taking the time to modify the cabinets inside this smaller building, an estimated $580,000 was saved.

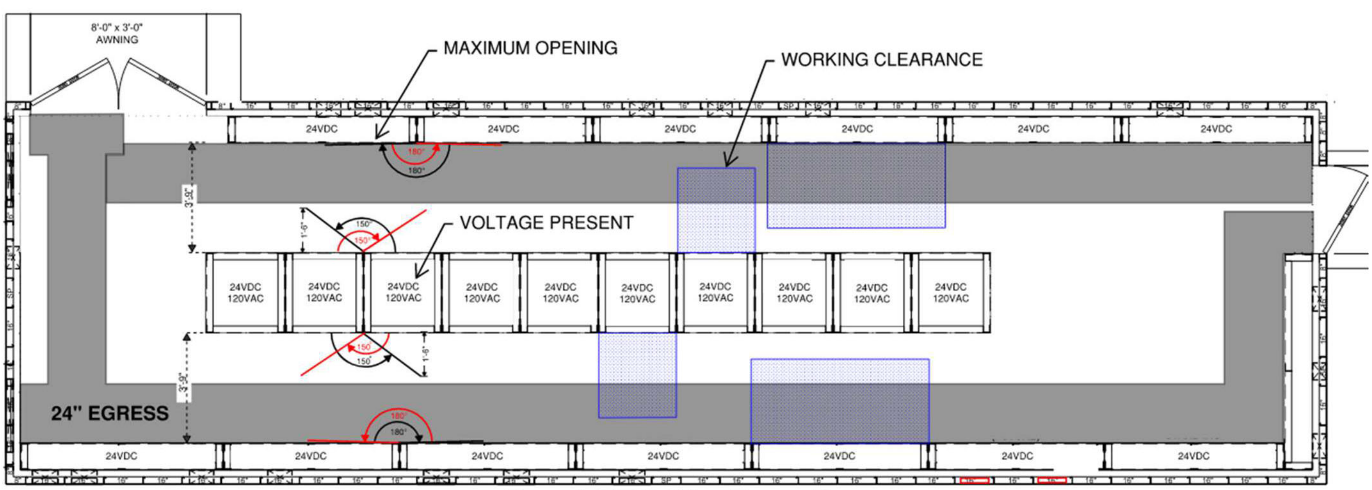

Figure 3 RIE Building Egress Plan

IV. MITIGATION STRATEGIES & PDC DESIGN

"You Get What You Specify, Not What You Want"

A. Institutional & Hospital Hinges
B. Bolt-On Doors
C. Bi-fold Doors
D. Sliding Doors
E. Roll-up Doors

Disclaimer: This list is not inclusive of all hinge technology but a discussion of findings to date.

Institutional / Hospital Hinges*:* Many cabinets can be specified or modified to have institutional or hospital hinges. These hinges are designed specifically for 180° door rotation while cabinets are mounted side by side. Designers must provide the desired specification for the specific hinge they want, as these specialized hinges have custom dimensions and load bearing capabilities. Details left open to interpretation by the vendor may have undesired results.

The primary difference between the two hinge geometries is that Institutional hinges (Figure 4) are designed to mount on the interior of the cabinet opening.

Hospital hinges (Figure 5) are designed to mount on the flanged opening of a cabinet and swing doors clear of the adjacent cabinet while bay to bay.

The load bearing capacity of a selected hinge for a door will impact the quantity and size of the hinge to be integrated. Material and weight of the door will also contribute to these factors. Aluminum doors are lighter than steel but often come at a higher cost. Door handle ergonomics should also be factored into the design to allow for maximum opening.

An assessment should be made to determine if the cost to integrate a recessed door handle is greater than the cost to lose a couple of inches of space in the aisle.

The cost to have cabinets modified will vary depending on a variety of factors including the extent of cabinet modification. Understanding the nomenclature and application can help reduce cost by specifying the best fit for each design.

Bolt-On Doors: This type of installation should be specified in cases where any angle of open door would block the path of egress in a workspace (Figures 6 & 7). If the doors are to be bolted on, it is recommended to use smaller bolted panels. See figure 8 where we chose 4 panels in lieu of 2. Bolt-on doors are great for rarely accessed equipment but are more work to remove and relocate. Depending on the weight of metallurgy, safety considerations should be considered when removing and handling such installations. One method for reducing the weight of a door is to break it up into smaller bolted sections; however, this may require additional mounting features to the cabinet.

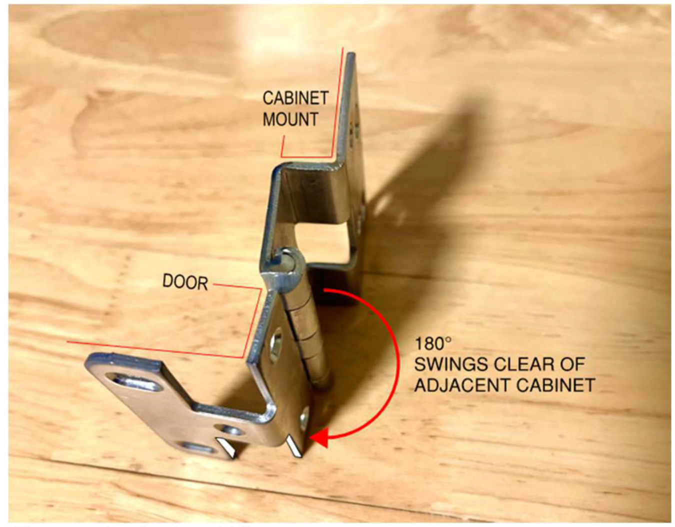

Figure 4 Institutional Hinge

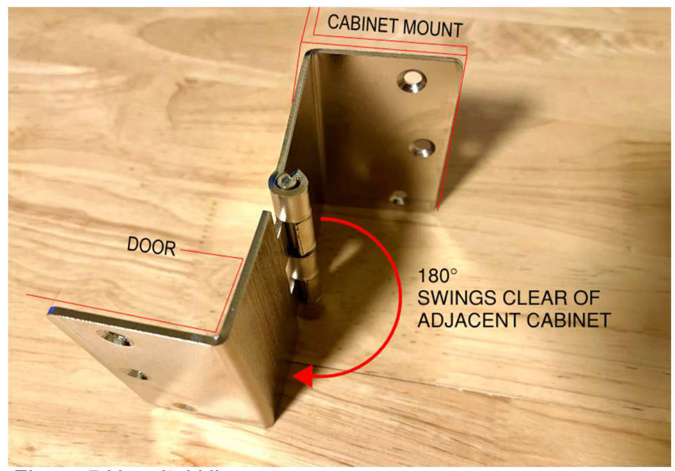

Figure 5 Hospital Hinge

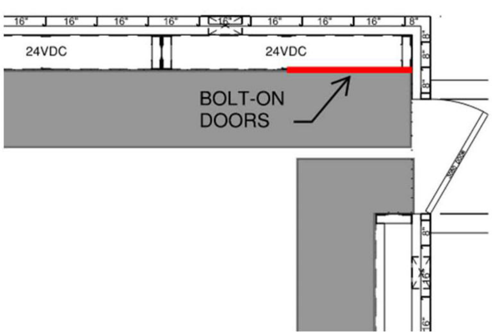

Figure 6 Bolt-On Doors

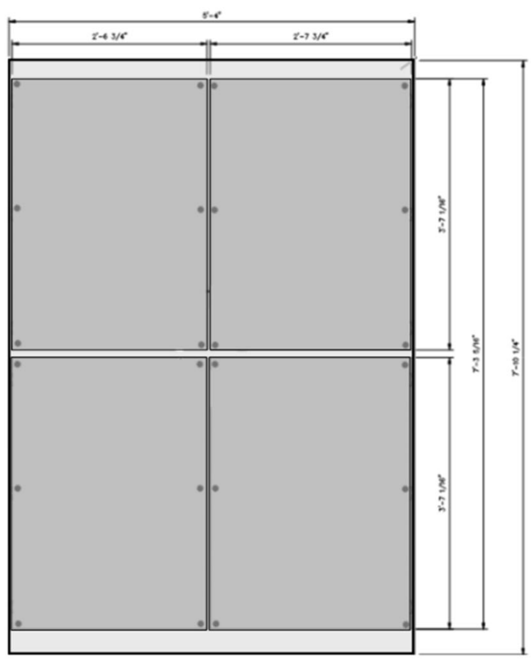

Figure 7 Bolted Sections Elevation View.

Bi-fold Doors: By adding a centralized hinge point, these folding doors are space saving compared to standard doors but do not provide as much clearance as institutional or hospital hinges (Figure 8). An internal rail system allows movement of the doors to slide open along a fixed track, which forces the central pivot point to move. This allows technicians to expose part or all of the internal cabinet but also creates pinch points while closing. These doors, also known as concertina doors, are a fine option when working in limited space but may not seal out dust or condensation as well as other options.

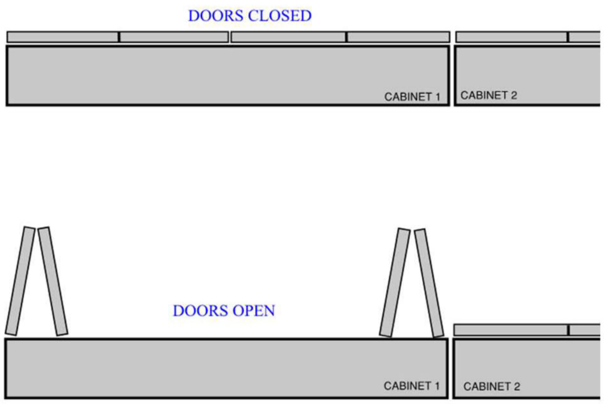

Figure 8 Bi-fold / Concertina Doors

Sliding Doors: Sliding doors are advantageous when it comes to clearance yet must be custom designed in each application to accommodate access to the equipment. Multiple rails, removable doors, or hinges may be needed to create the open space for doors to slide. Figure 9 shows an example of marshalling cabinets along the wall of an RIE using this principle. One major advantage of a sliding door is that egress determination is less of a factor and may simplify the approval process with local AHJs.

Figure 9 Sliding Doors on Marshalling Cabinets

Roll-up Doors: Another effective way to simplify approval processes with AHJ's and provide unobstructed egress from a building while using traditional working clearances is the roll-up door. Various manufacturers can provide a pre-framed roll-up door that will bolt directly onto an existing cabinet. These doors can be manually opened, motor operated, or spring actuated depending on specification.

It's recommended to specify the rotating axle to be on the outside of the cabinet when top-entry of conductors is desired (Figure 10). The bottom of the axle and optional cover must be located above NFPA 70 working clearance.

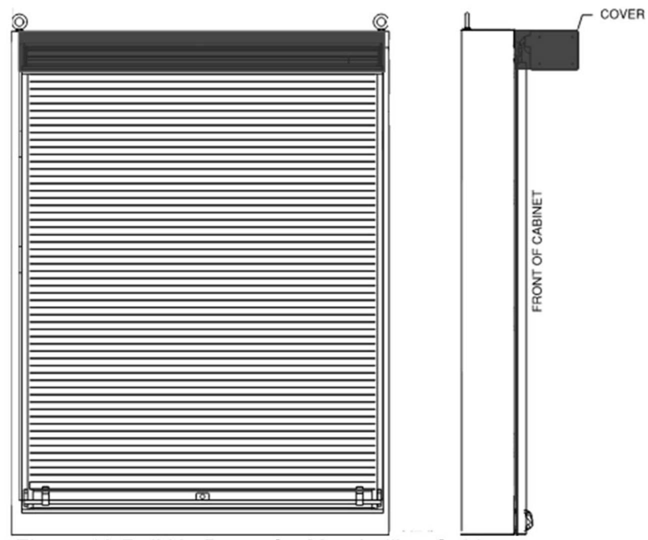

Figure 10 Roll Up Doors for Marshalling Cabinets

This solution is recommended for indoor locations such as purged and pressurized spaces that are naturally insulated from weather and contaminants and have been quoted competitively with hospital hinges.

Security Note: In many industries, DCS hardware is secured behind pad-lockable doors to prevent unauthorized access to the marshalling points. Consideration for each site's security plan must be taken into consideration as part of the design process. If lockable doors are not used, consider keycard access to the building itself, or discuss with the client about their site practices and needs.

The Worry-Free Solution: Build Larger Buildings - When physical footprint and project budget are not obstacles to the design, larger buildings are the best solution. Installation of bigger structures provides additional space for egress requirements, planned equipment, and future equipment.

While there is added initial cost to field labor and construction in the present, providing ample spare capacity and room for expansion may reduce regret spend later. Proactive planning to design buildings that are future proof, while considering the next 20-30 years of client needs versus project needs, ensures safe, reliable, and efficient use of space for years to come. Continuous discussions should be maintained with the client to consider how much future accommodation they are willing to invest in now to avoid regret spend in the future.

PDC Design Impacts and Considerations:

Figure 11 Assembly of A Prefabricated Substation

When designing a space for Switchgear or Motor Control Centers, it is worth making a determination about maintenance and installation equipment; Incase storage space should be allocated as to not obstruct egress.

Ground Test Devices (Figure 12) are large pieces of equipment that are often not considered because it isn't directly part of the switchgear line-up. Without planned storage space, technicians often leave these large and heavy carts in the aisle.

Figure 12 Ground Test Device

Breaker Lift Trucks (Figure 13) are also used to hoist breakers out of/into a line-up of switchgear. If space is not reserved or an alternate method provided for lifting breakers, there is a potential hazard to be left in the egress zone. Reserving a storage location where the lift truck will not be a tripping hazard in the walkway, using single-high switchgear, or installing an integrated hoist above the line-up are potential solutions.

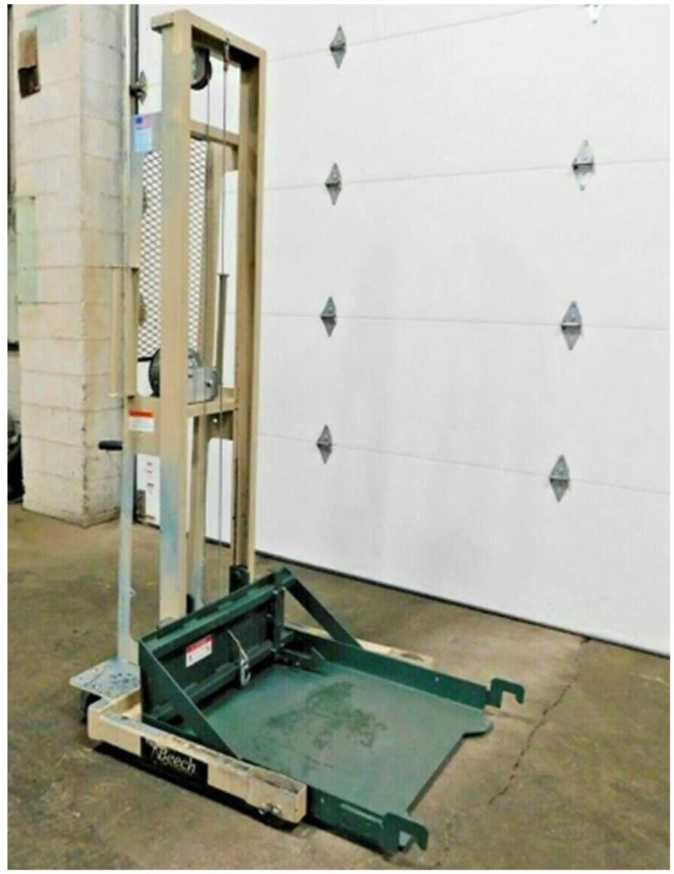

Figure 13 Breaker Lift Truck

A white paper initially published in 2023 and later revised in June 2024 (Magenes, 2024) discusses the impact of the 2023 NEC code change to PDC building design while also examining how PDCs will be constructed as the code is adopted. The paper highlights a point that is worth reiterating: code compliance needs to be evaluated in the early phases of planning and issued in the specification for the building being purchased. Failure to properly assess the egress or other code compliances can result in costly delays and/or redesign of the building.

In PDC type buildings it is typical to have multiple lineups of switchgear and other equipment of different voltage classes. These lineups are laid out on the floorplan in different geometries, often having switchgear facing each other. Figures 14, 15, and 16, illustrate how the NEC clearance provision evolved in subsequent editions of the code, starting from 2017. The figures show a schematic top view of an aisle between two lineups of switchgear that are facing each other. In the 2017 edition of the code, the minimum required aisle width was determined based on the minimum electrical working clearances required (NEC Table 110-34) depending on the voltage class of the equipment.

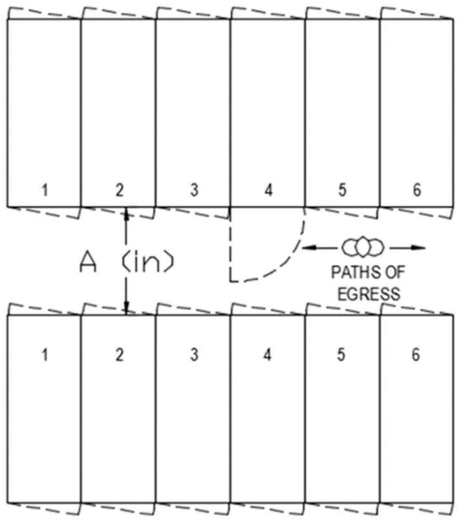

Figure 14. Schematic Aisle Size based on NEC 2017 (Magenes, 2024)

The 2020 edition of the NEC introduced new language on egress pathways, stating that a minimum 24-inch clear pathway is required in front of all large electrical equipment (6ft-wide equipment and wider) measured with the equipment doors open at 90 Degrees. This edition did not specify that the 24-inch minimum clearance be maintained with all equipment doors concurrently open on each side of the aisle. The representation of how the minimum egress clearance is maintained based on the NEC 2020 is shown below. For most equipment voltage classes, the electrical working clearances required will determine the minimum aisle width. However, there may be instances of specific switchgear or MCC that would require a larger distance between lineups. For example, in the case of a lineup with an oversized cabinet (i.e. for utility metering station), the larger door drives the aisle to be wider.

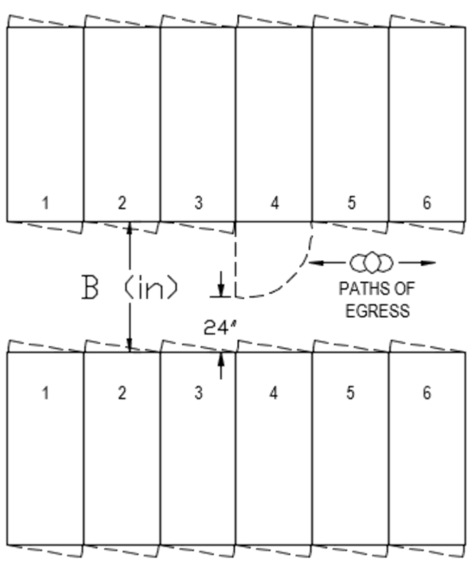

Figure 15. Schematic Aisle Size based on NEC 2020 (Magenes, 2024)

The 2023 edition expanded to include "…one or more simultaneously opened equipment doors".

Figure 16 below illustrates how this requirement is applied in the case of switchgear facing switchgear. The minimum aisle width in most cases now exceeds the electrical working clearance required for the voltage class of the equipment.

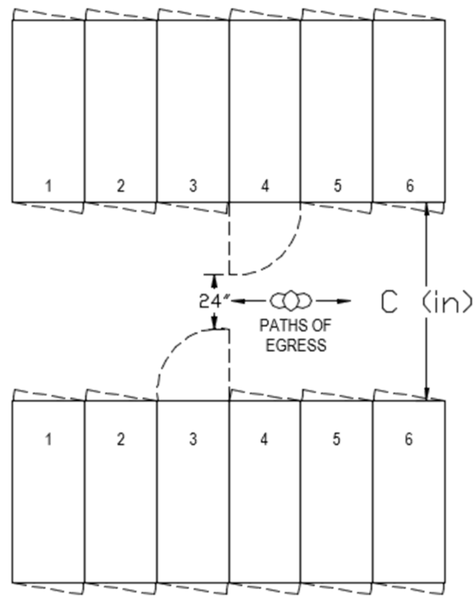

Figure 16. Schematic Aisle Size based on NEC 2023 (Magenes, 2024)

One additional note is that NEC 2023 requires that the egress be maintained for equipment regardless of size or voltage class of equipment. The 2020 edition only applied this requirement to large electrical equipment with a minimum lineup length of 6ft. A code change may be justified if access is provided for egress at either end of a line-up or from multiple locations in the space.

A way to mitigate the overall square footage of a PDC building is to build them longer; with fewer parallel runs of switchgear. Unfortunately, beyond trying to reduce the instances of equipment doors facing each other, there are not many "creative" solutions to work with the current code that are cost-effective and save space.

In contrast to instrument cabinets and panels, switchgear are heavily regulated in terms of design, especially if they feature Arc Resistant construction. Changing how switchgear doors hinge while opening would require manufacturers to design prototypes and may involve costly re-certification through testing.

Key Takeaways:

- Each of the cost-mitigation options presented has advantages and disadvantages that should be considered in the selection of engineered equipment.
- All projects are open to interpretation by each inspector and interpretation of the code is subjective beyond what is explicitly stated.
- It is recommended not to underestimate the impacts that last minute redesign or Q&A with the state AHJ's can have on the project. Impacts to both cost and schedule can be severe.
- Designers should consider additional large maintenance equipment that may be stored in the building and allocate space in the plan.
- While methods can be used to reduce costs and preserve space in low voltage equipment, switchgear and motor control centers do not have the same luxury of design flexibility. The code change proposal seeks to provide a different measurement for egress for MCC's and switchgear while providing equitable safety.
- The code change proposal included in this paper is a preliminary example. Feedback from engineers in the industry is encouraged to make a final assessment of its validity, and to explore any options not yet considered.
- By using hospital hinges in the case study of an RIE building, the client avoided unnecessary costs in the range of $580k which can be repeated in future designs onsite (Figure 17).

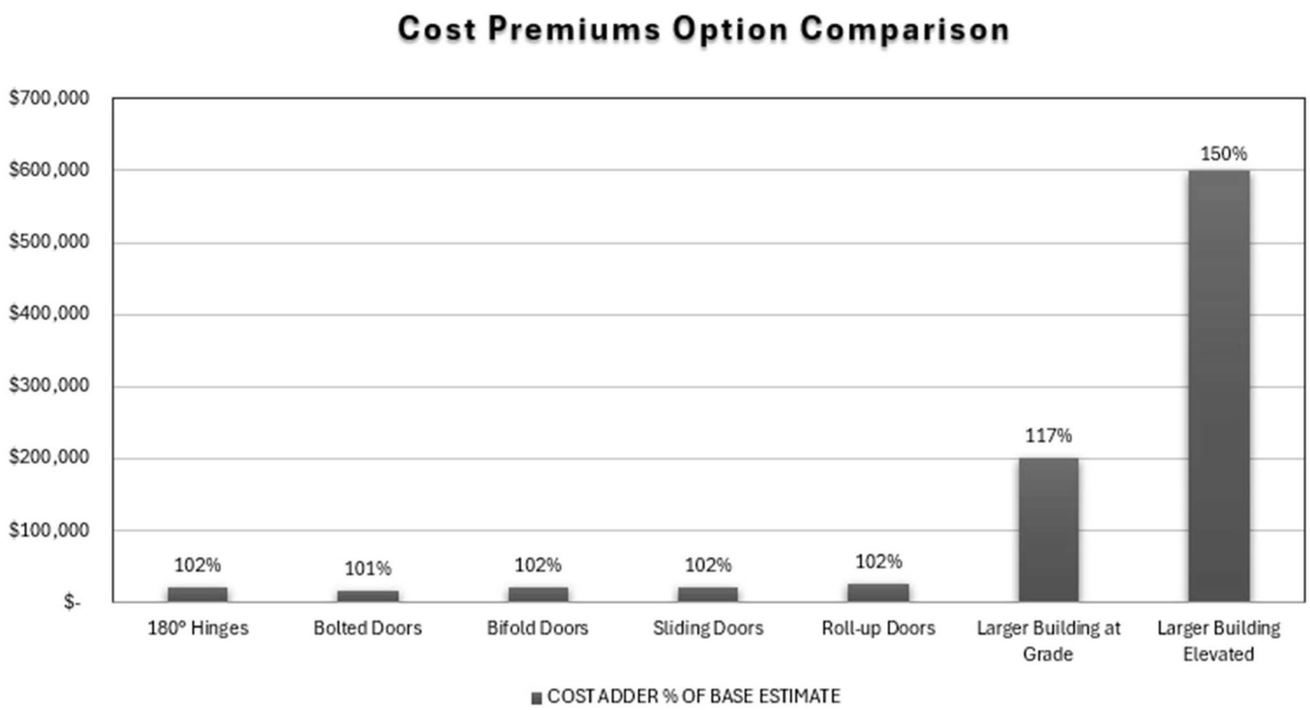

Figure 17 The expense of each of the options shown are conservative estimates based on quotes from vendors, engineers, and client estimators.

V. CONCLUSION

This paper includes a proposal and justification for amendment to the 2023 National Electrical Code (NFPA 70) regarding egress requirements. It also provides cost mitigation strategies for equipment not included in the proposed amendment and a case study to explore findings to date.

The NEC is a national standard interpreted and enforced by local authorities. The authority's jurisdiction differs from state to state and local adoption dates should be observed. Many AHJs treat permit applications as a competitive bid, and as such, each project and interpretation are subjective to local inspectors. Adding more transparent language to the NEC will help authorities establish a practical standard for interpretation and enforcement.

Engineers are encouraged to become more familiar with current door technologies to provide safe value-engineering solutions for clients and to coordinate with manufacturers to include egress in their standard products. Where possible, industries should consider a variety of equipment layout options in early phase planning to best use the available real estate.

We find it important to note that these code revisions improve safety in the workplace and reduce litigation costs from events that are used as a basis for development of the existing code requirements. Any recommendation for code change should seek to facilitate equitable or greater safety than the existing language.

The intent of this paper is to drive the discussion for a new code revision while also aiding others in developing safer more economical buildings. As an industry we find ourselves reacting to code changes more often than proactively participating in the process of code development. We encourage IEEE-PCIC members to be a part of the process and aid the NFPA council in developing comprehensive safety practices.

VI. ACKNOWLEDGEMENTS

Special thanks to Erik Jonson and Frank Bresnan for their insight and guidance.

VII. REFERENCES

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VIII. VITAE

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Joe Coder, E.I.T. has 12 years of Electrical Engineering experience in the petroleum industry, with a strong focus on refining processes. Throughout Joe's career, he has developed a deep understanding of the complexities and challenges associated with refining operations. Currently, Joe is an Electrical Engineer at the bp, where he contributes to the optimization and maintenance of electrical systems, ensuring the refinery operates efficiently and safely.

Mitchell Roegele Jr graduated from Washington State University in 2020 with a BSEE. He started his career as an electrical engineer for Anvil Corporation of Bellingham WA in 2020. In 2022, Mitchell took a job at the bp as a Discipline Electrical Engineer providing engineering support for large power distribution projects, operations, maintenance, and turnarounds.

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