Title:

Expanding an Existing Substation in an Operating Mine's Condensed Footprint

From:

[redacted]

[redacted]

[redacted]

[redacted]

Mining

[redacted]

[redacted] 2025

Declaration of Sole Authorship

I, [redacted], confirm that this work submitted for assessment is my own and is expressed in my own words. Any uses made within it of the works of any other author, in any form (ideas, equations, figures, texts, tables, programs), are properly acknowledged at the point of use. A list of the references used is included.

[redacted]

Signature [redacted]

[redacted]

Date

Proposal

A 100-year-old active mine site with a substation that was installed in 1965 is due for an upgrade. There are multiple contributory factors in the requirement to replace. The first being the age of the substation, and its equipment being at end of life although there's a remaining mine plan exceeding the year 2060. The second, being the need for more power to not only go deeper, requiring more ventilation and cooling but also greener, thus eliminating Diesel vehicles and going electric. The challenge with the upgrades is not only a limited footprint for expansion/ replacement but the inability to decommission the existing substation in order to build the new one as the mine must remain active.

The service life of the existing power equipment has been reached and the substation requires significant upgrades for the mine to continue to operate, however has limited space available to retrofit the new and additional equipment needed. Having to maintain power to the existing substation during the building phase adds complexity as the regulations require clearance from live electrical equipment to construction equipment. The methodology that will be used to solve this problem will begin using laser scanning technology to develop an accurate 3D as-built point cloud of the existing site and all the surrounding infrastructure. A trade-off study will then be performed to analyse the multitude of layout options that respect limits of approach to existing live equipment as well as the OEC electrical clearance requirements (live to ground, phase to phase, and live to adjacent steel). During the trade-off, an analysis will also be done to evaluate the impact a lattice type structure can have on the footprint versus the alternate and equally as common HSS type structures that can be used to support electrical equipment. It will also consider the site-specific clearance requirements for items such as transformer oil containment that will impact the amount of space required to complete the installation. Additionally, the existing pole line will be taken into consideration as a temporary feed may be required in order to allow power to be maintained for the entirety of the construction phase. The above mentioned will be done using the aid of 3D modeling of the substation equipment, the foundations and the required supporting steel directly within the as-built point cloud to be certain all regulation requirements for clearance have been met and in the most cost-effective way (as far as the civil construction is concerned). Finally, in order to maintain power, the project construction will be planned with the help of the three-dimensional model and phased appropriately to pre-determine when shutdowns are required limiting down-time to the mine.

I hypothesise that with the use of 3D technology, we can safely and effectively complete the retrofit of this large substation into a condensed and active area of the mine surface yard by simulating multiple iterations of the potential final layout within an accurate point cloud model of the existing footprint, all while respecting codes, site specifics standards, and operational requirements.

Proposal Approval Email

Outlook

Technology Report Proposal Satisfactory

From OACETT <certify@oacett.org>
Date Thu 2024-12-19 10:52 AM
To [redacted]

OACETT

Dear [redacted]

Your Technology Report Proposal has been ACCEPTED as SATISFACTORY and you have been assigned a one year deadline to submit the Technology Report - deadline extended to March 20, 2025.

The Technology Report can be submitted through your OACETT portal account by selecting your C.E.T. application.

Please consult the Technology Report Guidelines found here for more information.

Please retain this letter, for it must accompany a copy of your Technology Report Proposal and be included in your Technology Report submission.

If you have further inquiries regarding your certification, these can be sent to us at certify@oacett.org

Sincerely,

OACETT
Office of the Registrar

OUR CERTIFICATION | YOUR SUCCESS

Ontario Association of Certified Engineering Technicians and Technologists
10 Four Seasons Place, Suite 700, Toronto Ontario, Canada M9B 6H7
www.oacett.org | info@oacett.org

Executive Summary

Mining in [redacted] has occurred for over 100 years and has been a dominant contributor to the local economy. The industry is constantly evolving and searching for ways to continue production deeper than ever before but in a safer and cleaner manner. This presents a problem for most aging mine sites as it introduces technology such as Battery Electric Vehicles that require a larger power supply than is currently available. Most mine sites having been extensively developed are limited on space for expansion and cannot be taken offline to be replaced entirely requiring retrofits.

As detailed in this report, incorporating advanced survey technology such a laser scanning for developing an as-built of the existing infrastructure addresses a portion of this issue. When coupled with modeling directly within the point cloud, the substation design process can be streamlined. The result is a design that be viewed in 3D and optimized for code compliance, construction phasing and site-specific needs while increasing safety and limiting down time.

Table of Contents

List of Illustrations

1.0 Introduction

As is the industry trend, the [redacted] mining company in [redacted] is continuously performing exploration activities to continue production and expand the life of existing mine sites. Of the sites that remain active, their oldest [redacted] mine has discovered ore at depths greater than they're currently mining. These depths have always been out of reach to mine safely as ventilation and ground control become significantly more complicated the deeper the mine advances. The latest innovations such a battery electric vehicles and ventilation on demand begin to address these issues but in turn introduce the alternate issue of power to the equipment.

The entire underground operation at this site, with the exception of the skip hoist, is currently fed by a substation that was commissioned in 1965 and the majority of the equipment is at end of life and due for replacement. The skip hoist having its own substation that was commissioned in 2009 to begin the upgrade process. The age of the original substation, along with the need for additional power presents a problem for the mine site as it requires a bigger substation. The mine cannot continue to operate with the existing equipment as there is a high risk of equipment failure which would halt production and lead to extended down time. There is no space available near the existing hoist house/ switch room where the power is directed from the substation to the underground workings to construct a new substation altogether. Which leaves the only feasible option of expanding the near by skip hoist substation. This will address the current power loads needed to replace the aged substation while taking into consideration the future loads required to mine deeper.

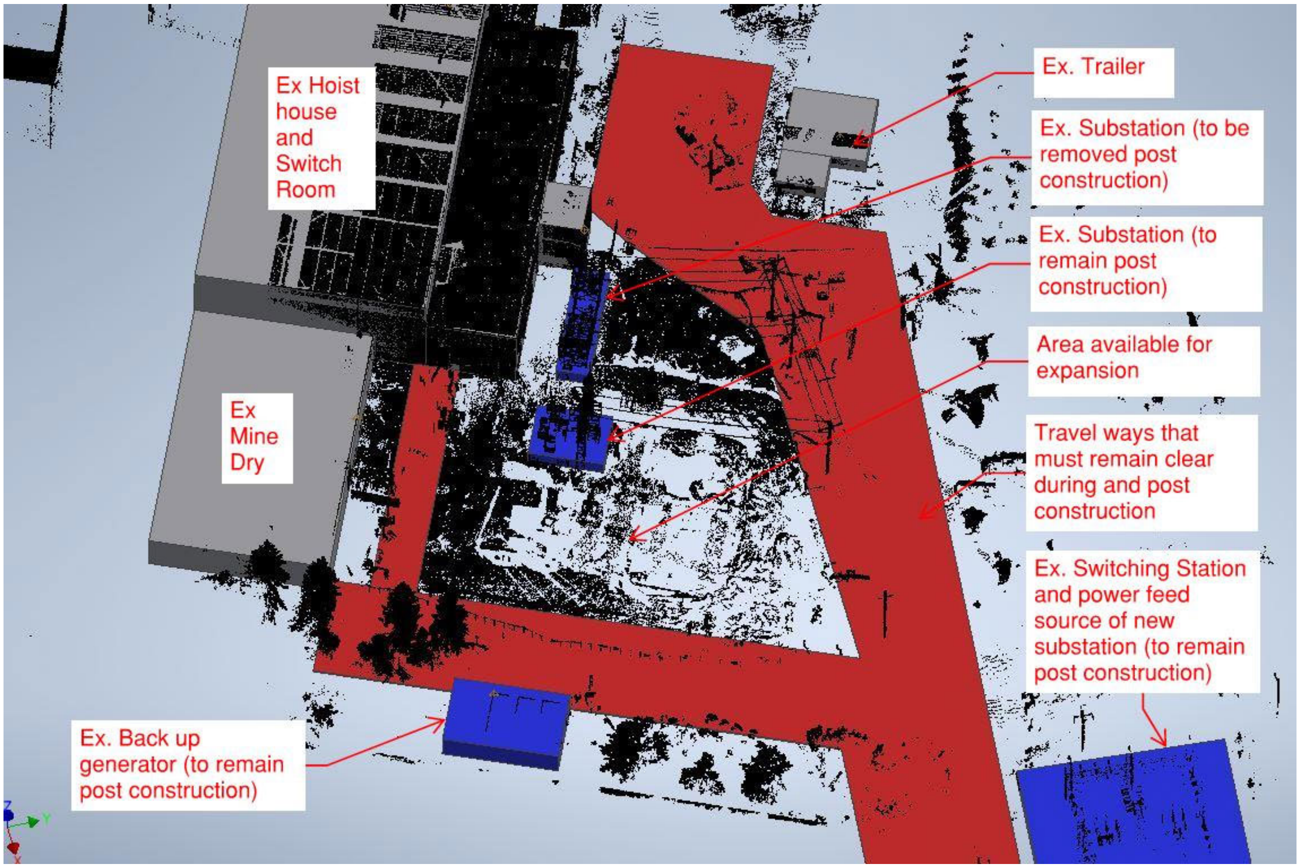
Although the only option for this site is to retrofit the existing substation it comes with a series of obstacles that will be outlined in the report. These concerns will be overcome using a variety of technologies such as 3D laser scanning and 3D modeling. The report will showcase the workflow for incorporating these tools into the typical substation design process all while adhering to the relevant substation codes and site-specific requirements.

2.0 Methodology

2.1 Power requirements and existing site conditions

In order to increase the size of an existing substation the 2 primary considerations are the additional power required and the available space within the adjacent area. The current and future power requirement will determine how much equipment needs to be placed in the area as well as the size of the equipment. The current substations consist of 2-10MVA and 1-25MVA transformer, respectifvely. It was previously determined that the 2-10MVA transformers are at end of life and although they need to stay active during the substation expansion construction, cannot be factored into the expansion. A power study therefore determined that the substation would need to be upgraded to a total of 4-25MVA 69/13.8kV transformers. This will add 3 large transformers as well as the required isolation and safety equipment to the existing skip hoist substation. While evaluating the footprint of an active mine site it is important to factor in how construction activities can interfere with current mining activities including the need for maintaining the existing substation, existing infrastructure, access roads, and lay down areas. An accurate depiction of the existing site and surrounding infrastructure can be captured using 3D laser scanning technology. This will allow us to not only capture all potential interferences at grade like a conventional survey but also those that are elevated such are pole lines. The initial survey can be seen along with all exclusion zones in Illustration 1.

Illustration 1 – Site Laser Scan Survey and Exclusion Zones



2.2 Determination of site-specific clearances

This specific site is located in Ontario therefore follows the clearance guidelines set out by the Ontario Electrical Safety Code (OESC). From a structural perspective, OESC Table 30 and OESC Table 32 as shown in *Appendix A* will be used to determine steel separation requirements as it pertains to live to steel, between live parts and live to ground clearance. A summary of the 69kV clearance requirements are listed in Table 1 below.

Table 1 – OESC clearance summary

Minimum Clearances for Maximum System Voltage of 69kV	
Live to Steel	740mm
Live to Live	790mm
Live to Ground (Heavy Snow)	4.6m

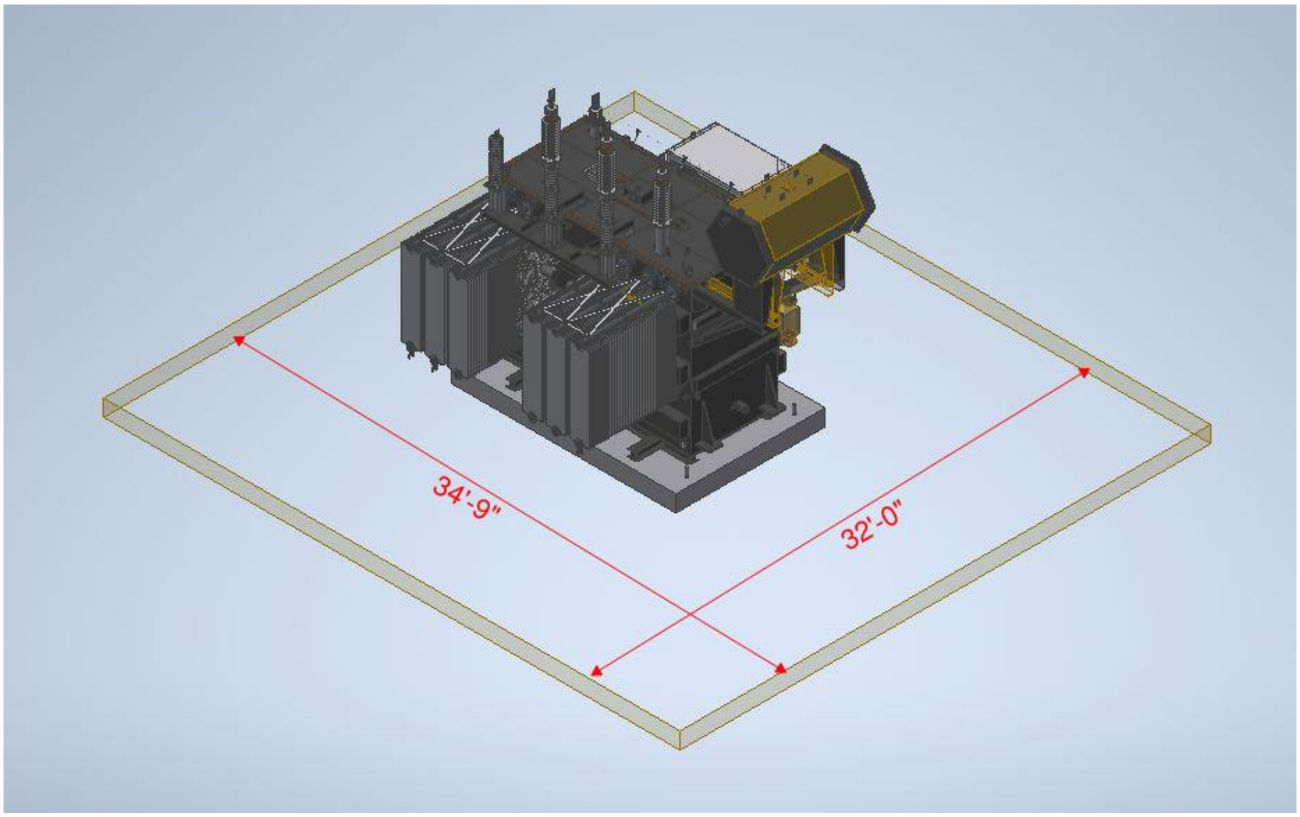
Additionally, the site also has specific requirements regarding asset protection (namely the Transformer) as set out by their insurer FM Global. These constraints as shown in *Appendix B*, defined by FM Global are regarding the need for a containment pit surrounding the transformer and the criteria for size and separation of the pits. These are all driven by the transformer size, amount of fluid and type of fluid. A typical 25MVA transformer layout (69/13.8kVA) can be seen on the drawing in *Appendix C*. The transformer as shown contains contains 3145 gallons of Voltesso 35 (mineral oil, non FM Global approved). The relevant requirements are summarized in Table 2 below for this application.

Table 2 – FM Global containment pit summary

Minimum Requirements for containment – 3145gal Mineral Oil Transformer	
Containment perimeter extents	8ft beyond oil containing parts
Separation between containments	25ft (from edge to edge of containment)
Firewall criteria (should separation not be met)	1ft vertically, 2ft horizontally beyond transformer

When combining the transformer data and the containment pit requirement its can be determined that the pit will have a minimum extent of 34’-9” by 32’ and is depicted in Illustration 2.

Illustration 2 – Containment pit extents



2.3 Layout configuration

Using the information provided in the 2 previous sections the layout configuration can be evaluated. Not only can it be determined if the transformers can fit in the allotted footprint within compliance but also the specific configuration to be used moving forward. For this application, an in-line arrangement and quad arrangement were evaluated. These can be seen below in Illustrations 3 and 4 respectively.

Illustration 3 – In-line transformer arrangement

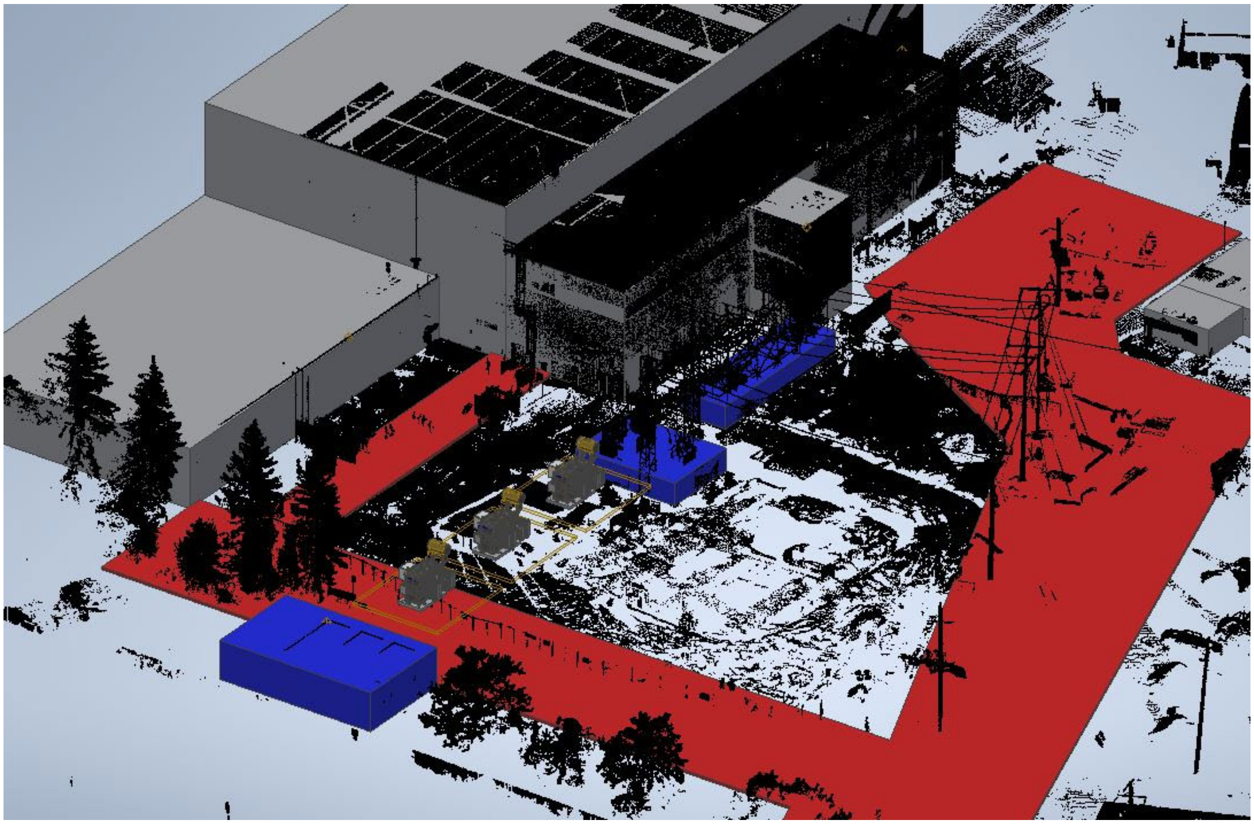
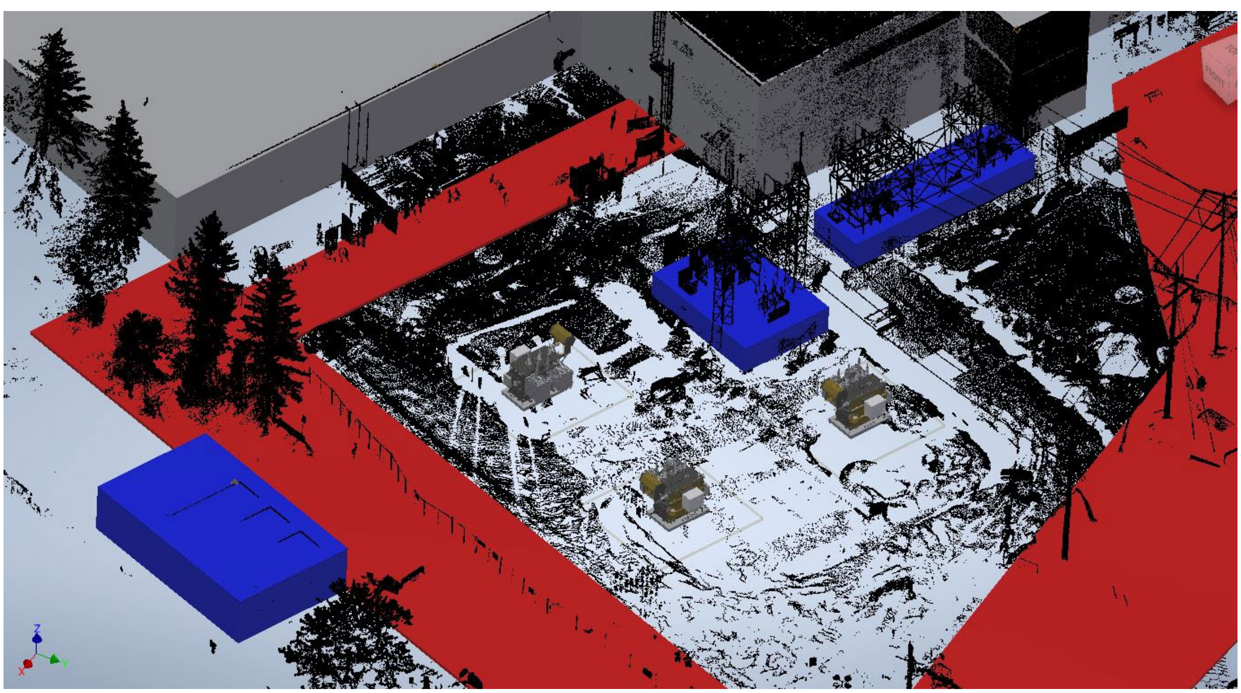


Illustration 4 – Quad transformer arrangement

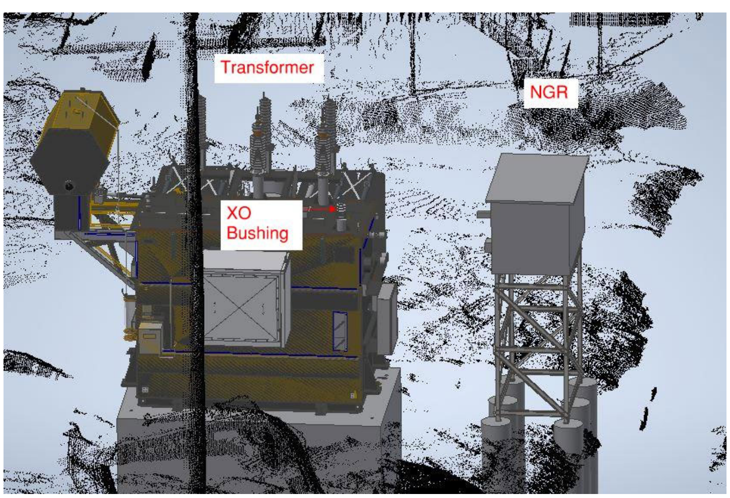


With these results, the only configuration that can explored further is the quad arrangement. The in-line option has been eliminated due to the encroachment on the travel way as seen on the 3D model. This option would also lead to issues with accessing and maintaining the existing generators.

2.4 Addition of isolation and protection equipment

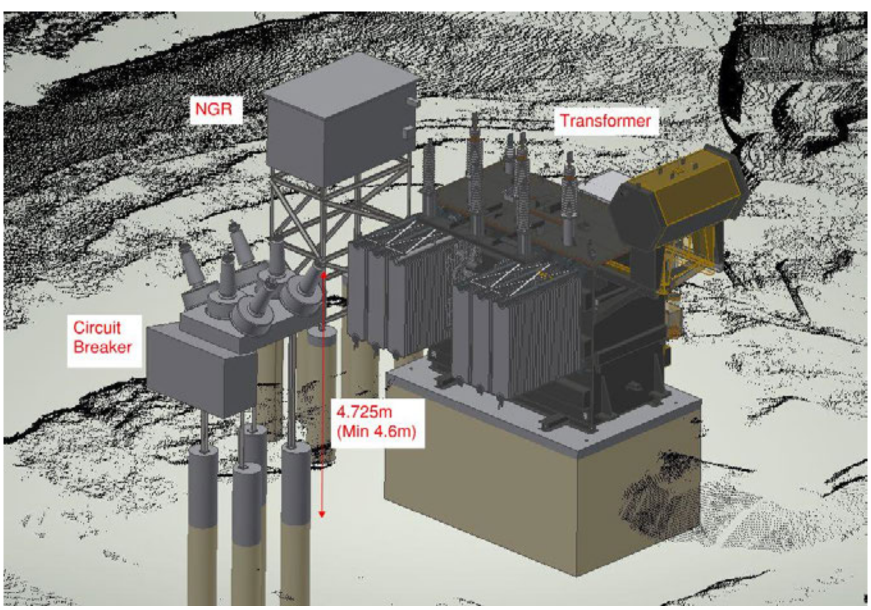
In order to meet codes and perform various maintenance activities each transformer will require a Neutral Grounding Resistor (NGR), a circuit breaker and a disconnect switch. Although these perform specific electric functions, they are critical to the Civil and Structural layout of the substation as the clearances play a role in the size of the steel structures and the overall footprint require to fit the equipment. The NGR connects to the XO bushing of the transformer therefore needs to be in close proximity to it and elevated to the same height using the vendor supplied steel structure. See *Appendix D* for typical 13.8kV NGR (lower voltage of the transformer). Although there is no set distance, it is important to place it so that access to both the transformer and the NGR can still occur, as shown in Illustration 5.

Illustration 5 – NGR placement



A circuit breaker is another imperative protection device to prevent faults from tripping the transformer. Its also allows for power to the transformer to be interrupted when in the open position. These are placed ahead of the primary of the transformer (higher voltage and incoming power side). When designing for the breaker placement it is important to place it at a distance that a support structure can be installed, whether it be free standing of overhead. This is to prevent side loading the transformer bushings causing issues with the seals at the base of them. It should also be noted that the breaker concrete be at a height so that the Live to ground clearance is respected, as the breaker bushings are exposed. As mentioned in Table 1 above, this distance is 4.6m for areas of heavy snow, which this mine site can experience. A typical 69kV breaker drawing is attached in *Appendix E*, this shows a live to live parts of 3178mm therefore the concrete will need to be a total of 1422mm (roughly 56”) above the substation final grade. A grade plane has been added to the 3D to allow for quick verification of this dimension, ensuring code compliance. This can be seen in Illustration 6 below.

Illustration 6 – 69kV Breaker Clearance

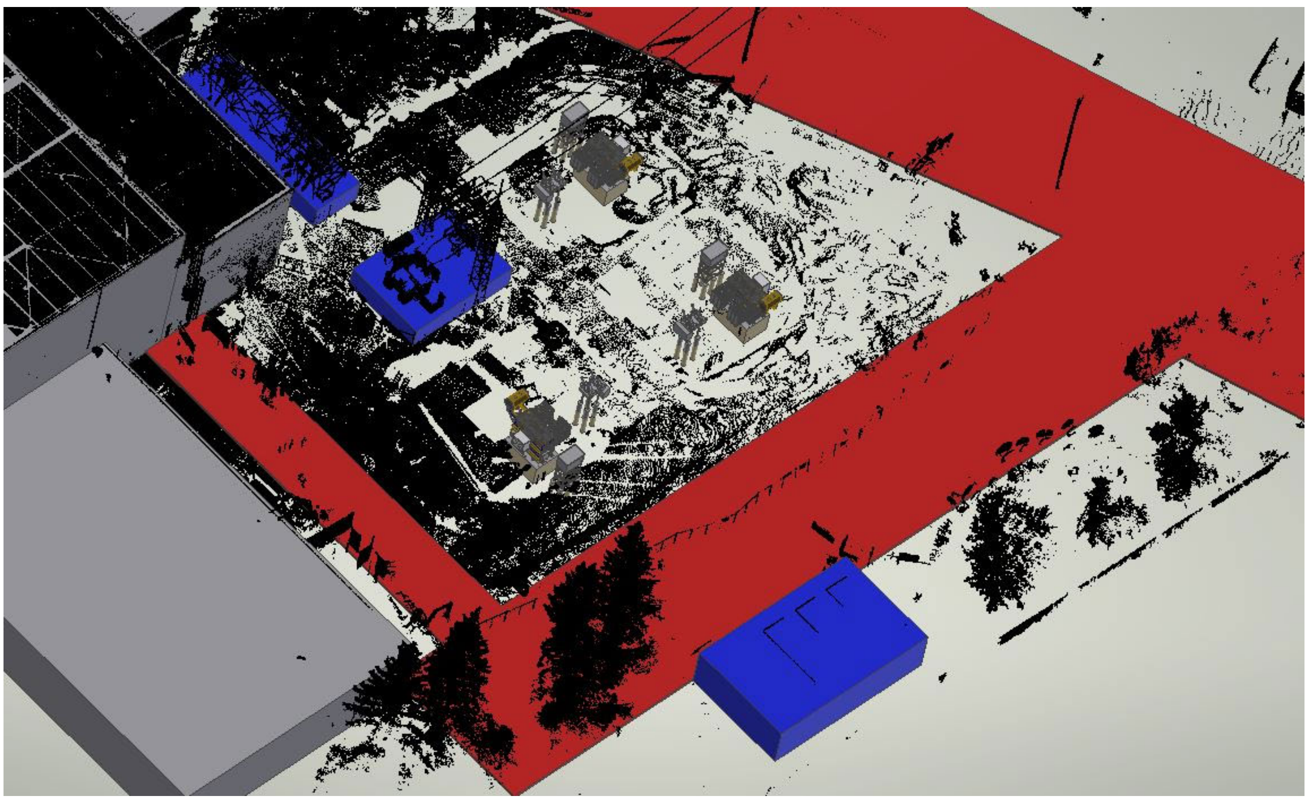


As mentioned above each transformer also requires a disconnect switch however placement will be evaluated later in the design as it is dependant on the structure type.

2.5 Overall substation footprint

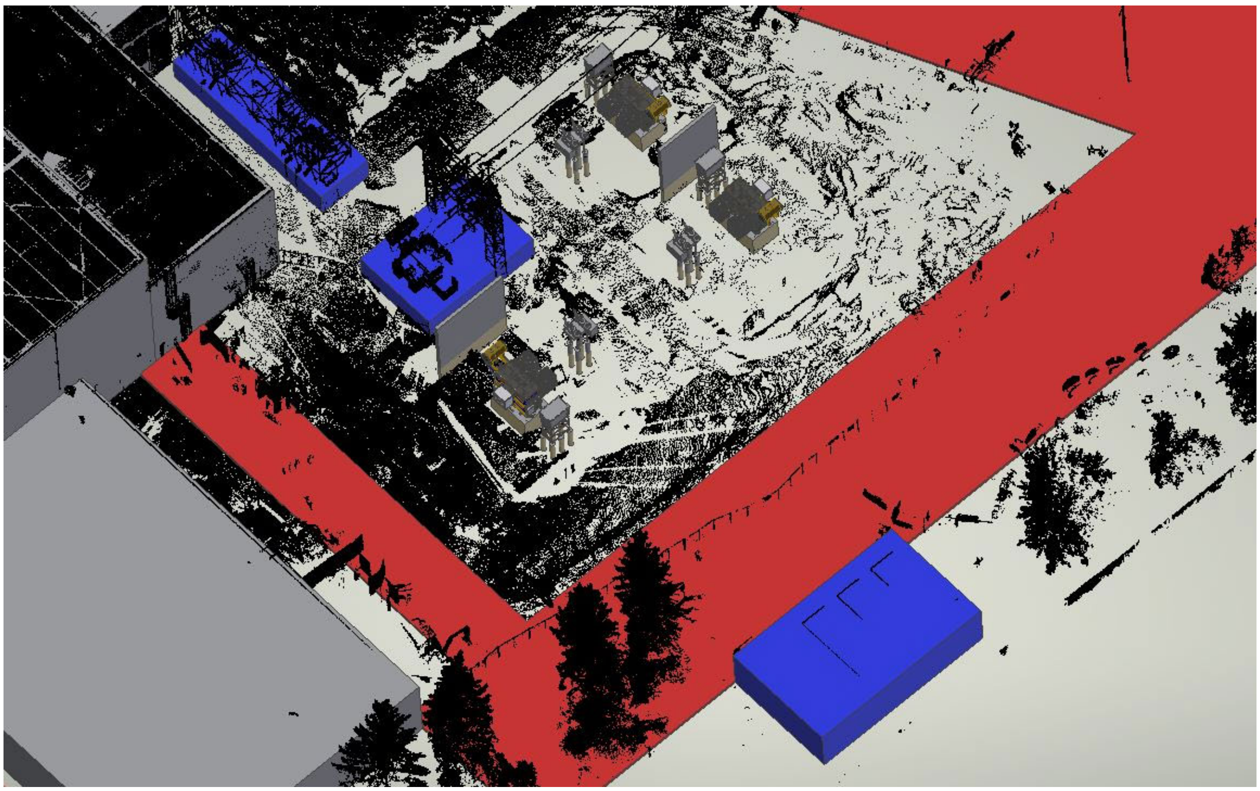
Once all the major equipment has been modelled in, an appreciation for the overall size can had to determine if any optimization is required. The current design respecting the FM Global requirements for containment spacing can been seen in Illustration 7.

Illustration 7 – Substation layout



Although the substation has successfully been contained within the allotted footprint, the transformers at the south of the substation along with the addition of the equipment will force the fence line closer towards the travel way between the substation and the existing generators. This could lead to potential issues for maintaining or even replacing those generators should they fail (emphasis on this due to crane placement). With this in mind, there is opportunity to condense the footprint further by introducing firewalls to the substation. The result of this optimization is shown in Illustration 8 below.

Illustration 8 – Optimized substation layout



The addition of the firewall does reduce the overall substation (approx. 15’ across the south side) and allows for better access to the generator area. Although this comes at a cost for the construction of the firewalls, that cost is largely offset by the reduction is excavation, backfill, and grounding that is eliminated due to the smaller footprint.

As mentioned in Table 2 above, the firewall be 1ft vertically and 2ft horizontally beyond transformer for the site to be deemed compliant to the insurer. In this particular case, the firewalls will need to be 2 different sizes due to the existing transformer and its size differential. As shown in Illustrations 9 and 10, the combination of the model and laser scan is a great tool to quickly evaluate required size and confirm compliance. The result is one firewall that is 24’Wx22’H and another that is 20’Wx17’H.

Illustration 9 – Firewall plan view

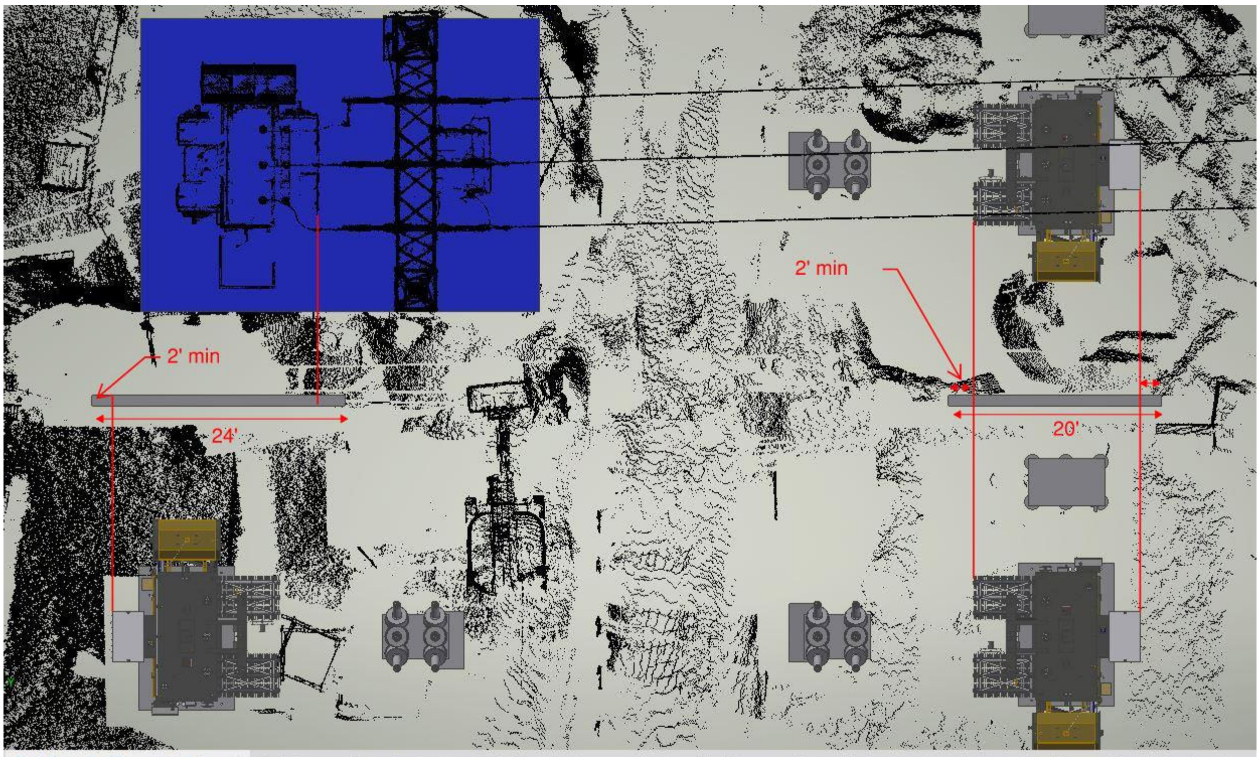
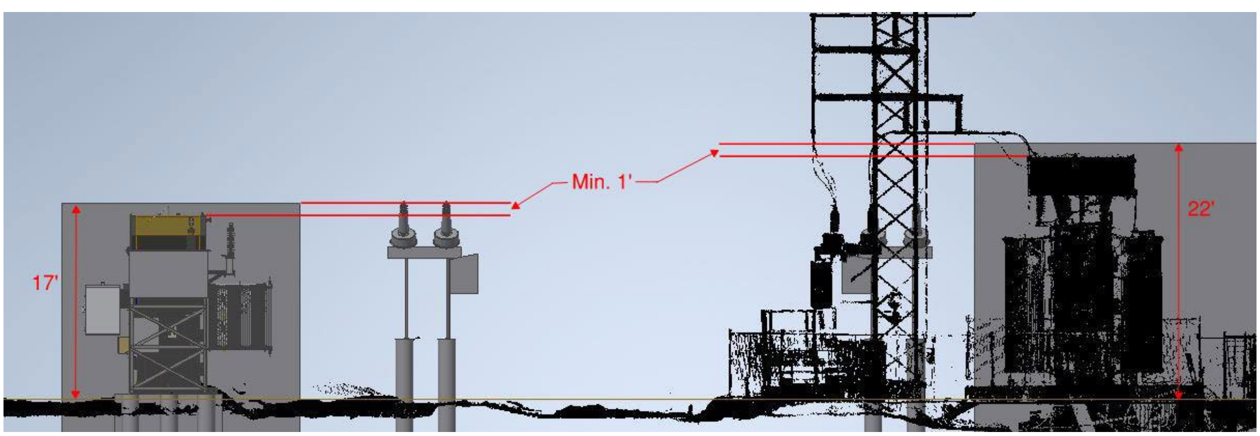


Illustration 10 – Firewall elevation view

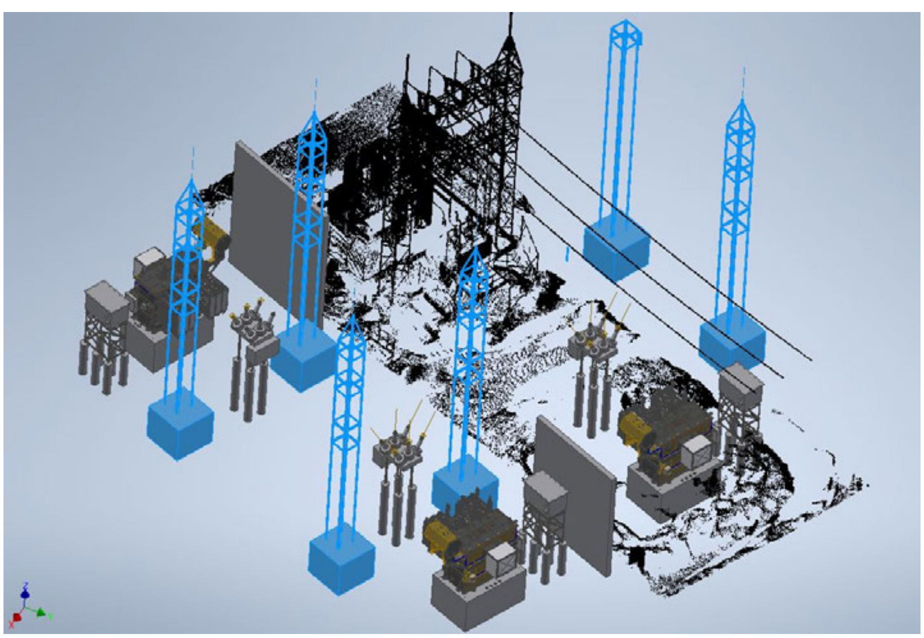


Although it would have been beneficial to also reduce the footprint in the East West direction, the larger opening will serve as a power corridor. Therefore, no further optimization is needed.

2.6 Trade off analysis: Lattice vs HSS structures

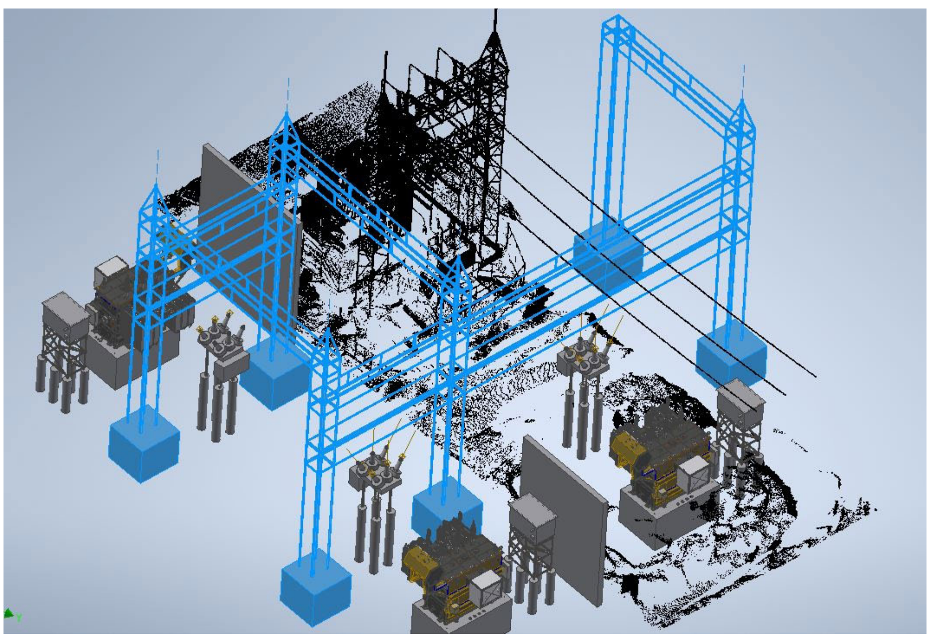
In order to bring power to the transformers the centre aisle will be used to establish a high and low bus system. This will allow power to flow through either end of the substation in the North/South direction on a high bus (this refers to it physical location not voltage), then drop to a low bus to feed each transformer. This style is required due to the quad arrangement and the inability to direct feed each transformer from a pole. This will be achieved using either a lattice style gantry or individual HSS structures. For the lattice style gantry there would be 6 towers complete with foundations required, 2 at either end of the power corridor and 2 in the center of the transformers as shown in Illustration 11.

Illustration 11 – Gantry Towers



The height and size are each tower is designed to match the existing gantry structure of the substation. At each transformer, 2 girders are required. At each transformer, 2 levels of girders are required. The lower one for the disconnect switch should the breaker or transformer need to be manually isolated. And the higher of the girders will be for the low bus. Finally, the highest level of girders will run between the towers perpendicular to the power corridor and will support the incoming lines as well as the high bus. This can be seen in Illustration 12.

Illustration 12 – Gantry Towers and Girders



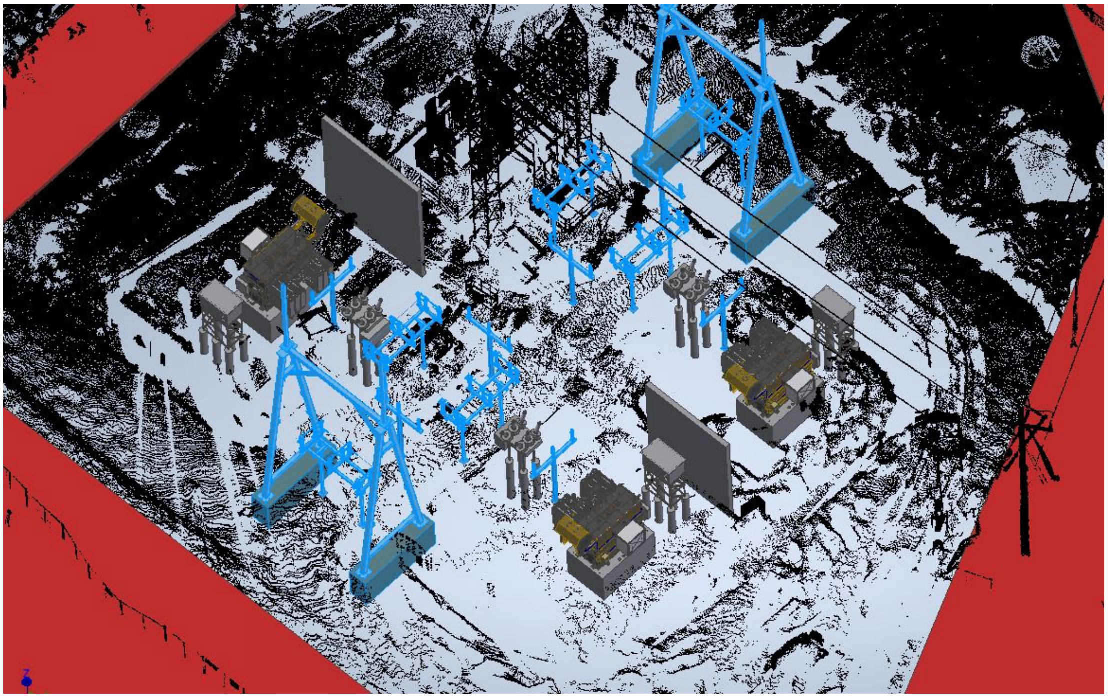
Using the 3D model it is possible to quickly to quantify the steel and concrete required for this type of installation. The steel is calculated using the physical properties directly in the software and is approximately 25,000kg. As for the concrete, an 8'x8' gantry foundation was assumed. This allows not only sufficient space to anchor the 4'x4' gantry tower, but additional space for operations to stand on the concrete to perform various maintenance tasks. A total height of 11' was carried for the foundation assuming 1' above grade and 10’ below grade to bed rock. This is a standard depth to bedrock for this site and due to the height and nature of the gantry these foundations require anchoring to bedrock. This is a total of 704cuft per foundation which equates to 4,224cuft for the entire gantry. This is summarized below in Table 3.

Table 3 – Material take-off for gantry

	Item	Weight	Quantity	Total
Steel	Gantry	20,355kg	1	20,355kg
	Item	Volume	Quantity	Total
Concrete	Gantry Pier	704cuft	6	4,224cuft

To achieve the same results using the HSS style a variety of structures will need to be used. The incoming power will need to be dead-ended using an A frame style structure, this will occur at either end of the corridor and will require 2 concrete piers per dead end. These piers will need to longer due to the spread stance of the structure but are narrower. For estimating purposes, they are assumed to be 4’x18’ with the same total height of 11’ and will therefore require 792 cuft of concrete each. All remaining structures will make use of the same pier and footing style foundation. This will allow for a shallower installation only requiring the underside of the footing to extend beyond frost which is known to the 6’ deep at this site. The total foundation height will be 7’ when taking into account the typical 1’ above grade. The pier portion will be 2’x2’ and 6’ high with a footing that is 6’x6’x1’ high. This is a total of 36cuft per foundation. Following the Dead End Structure mentioned above, there is a disconnect switch that will be on its own support structure on either side of the corridor. This type structure will require 2 of the above noted foundations. The disconnects will then be connected from one end to the other using bus bar that is supported by a series of high bus structures. A total of 4 structures is assumed to be required to complete the power corridor. Each of these structures will require 1 foundation. From the high bus, power flow to a low bus that runs perpendicular to the power corridor. The low bus will be supported directly on disconnect switches (and their structures complete with 2 foundations) at each end. The switches will feed power directly to the breaker which does not require additional support, then from there it goes to the transformer. An additional cable support stand will need to be installed between the breaker and transformer in order to avoid side loading the transformer bushing. This support stand will use a T shape and only require 1 pier per structure. This is can bee seen as described in Illustration 13 and summarized in table 4 below.

Illustration 13 – HSS Layout



*Only structures shown and elec bus bar omitted for clarity

Table 4 – Material take-off for HSS Structures

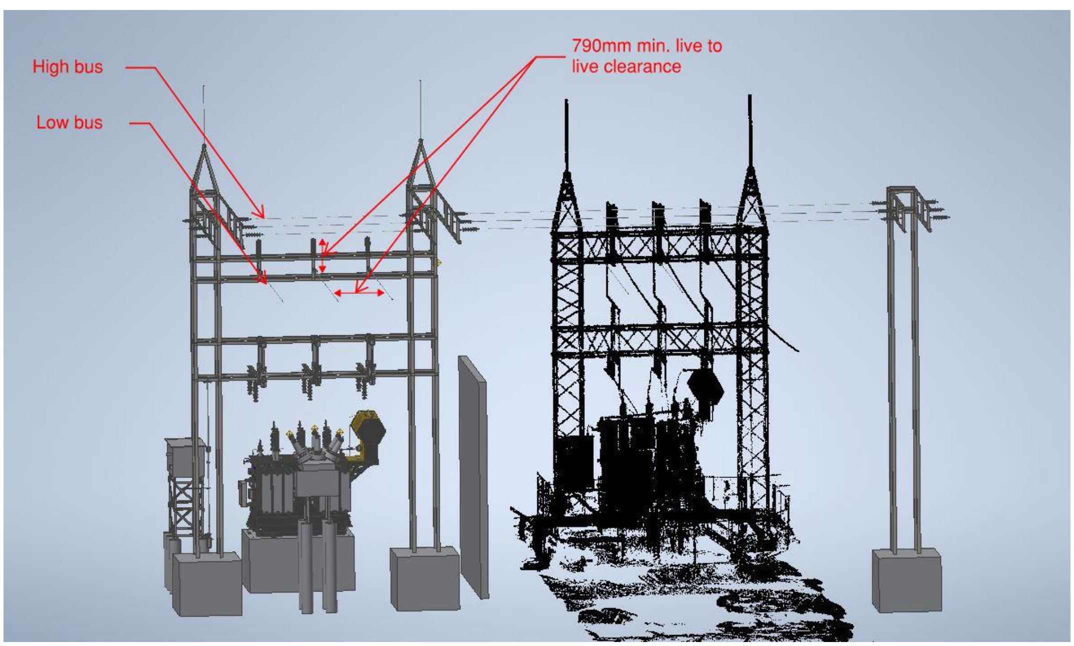
	Item	Weight	Quantity	Total
Steel	Dead End Structure	7,000kg	2	14,000kg
	Switch Structure	810kg	6	4,860kg
	High Bus Structure	425kg	4	1,696kg
	Cable Support Structure	235kg	4	940kg
	Total Steel			21,496kg
Concrete	Item	Volume	Quantity	Total
	Dead End Pier	792cuft	4	3,168cuft
	Switch Str Pier	36cuft	12	432cuft
	High Bus Str Pier	36cuft	4	144cuft
	Cable Support Str Pier	36cuft	4	144cuft
	Total Concrete			3,088cuft

Although both options seem comparable in material, a few key considerations should be made that make the gantry option more feasible for this specific project. In the HSS option, the concrete volume is lower however it requires 24 smaller piers with footings. This greatly increases the amount of formwork required for cast in place construction thus elevating the cost to build. Due to the presence of an existing gantry, it would be difficult to complete a tie into the existing transformer with the HSS style, where as the gantry can be retrofit to match it. In order to maintain proper electrical clearances, the power corridor would need to be widened for the HSS style compared to what the gantry allows for. The gantry has masts above each tower providing lightning protection for the entire where as the HSS style only has them on the dead end. The HSS substation would likely require at least 2 more stand alone lightning masts to provide adequate protection. This however would need to be confirmed by lightning study. Finally, due to the use of elevated strain bus in the gantry option, the power corridor is wide open at grade and can serve as a travel way. Which greatly improves access to all the equipment for maintenance and replacement.

2.7 Finalize substation model

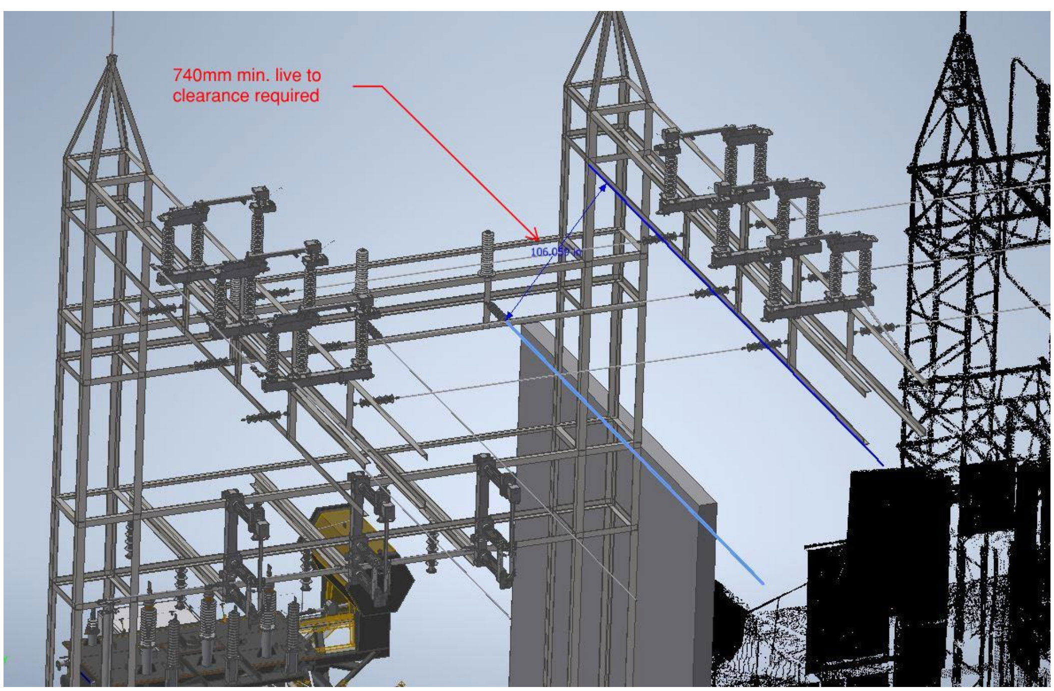
The gantry layout and size were limited due to the existing gantry and the need to tie into it. This applies to both the tower locations as well as the girder placement between the towers for the transformers. Although the girders at each transformer were a replica of the existing substation the girders supporting the high bus required additional evaluation to ensure proper separation between conductor phasing (live to live separation). This can be seen in Illustration 14.

Illustration 14 – Bus live clearances



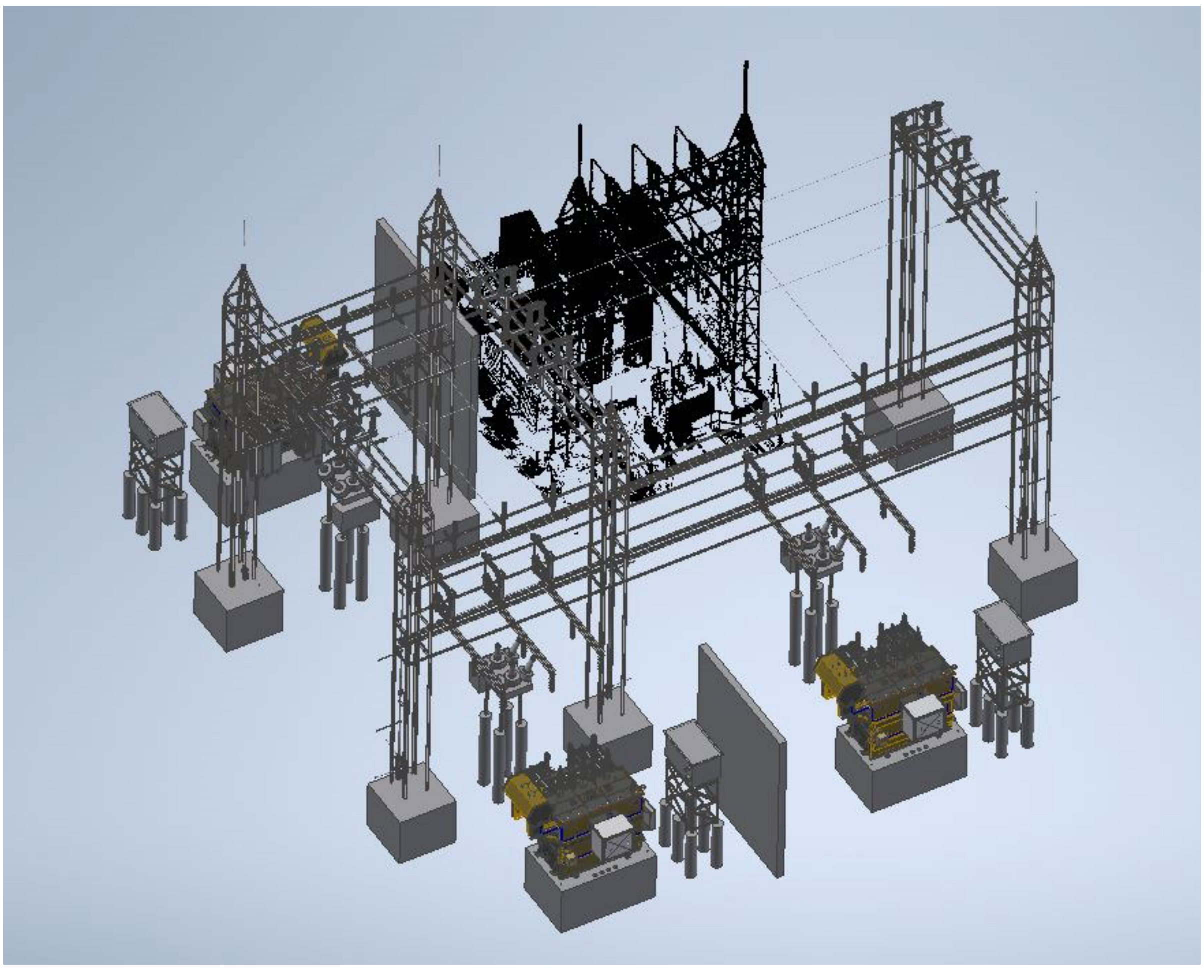
As noted earlier in the report, the live-to-live clearance required by OESC for a voltage rating of 69kV is 790mm. Therefore, the low bus girder was set in line with the existing incoming power line and the high bus girder was then set 8' higher. Although this exceeds the requirement when evaluating a perfect elevation view, it avoids the bend radius of the cables from the equipment potentially encroaching on this clearance. The next step for evaluation is the conductor spacing with either the low bus or the high bus system. This matches the disconnect switch phase spacing set by the manufacturer. A typical 69kV disconnect switch outline can be seen in *Appendix F.* For this model spacing of 7' was used as per the outline drawing. Once all the strain bus and switches have been added to the model a final review can be performed to check all the potential live to steel clearances. As noted earlier in the report, the live-to-steel clearance required by OESC for a voltage rating of 69kV is 740mm. An example of this can been in Illustration 15.

Illustration 15 – Steel live clearances



These checks can be carried out through out the model, ensuring OESC compliance and when complete the model can be deemed final and used to produce engineering drawings that can be issued for construction. See Illustration 16 for final model of the substation.

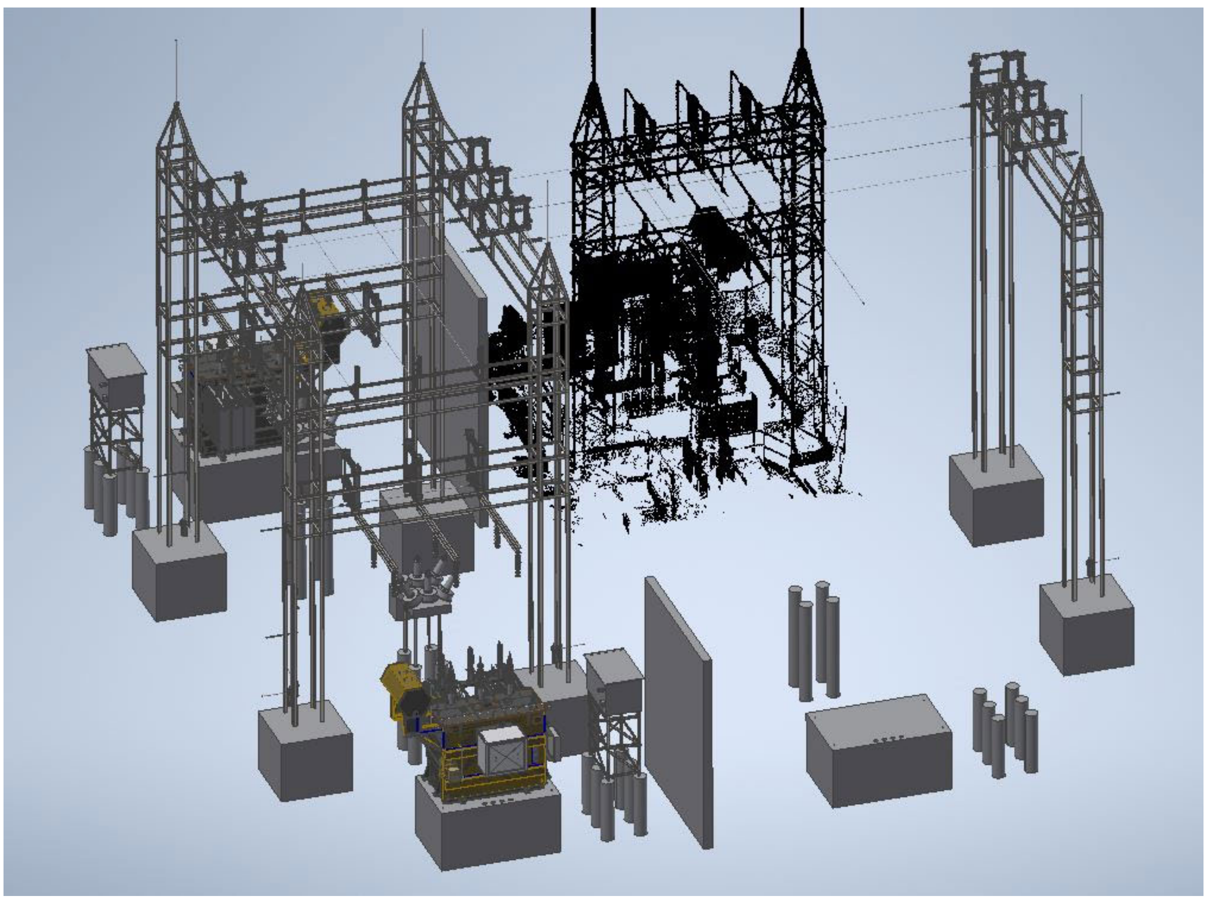
Illustration 16 – Final substation model



2.8 Pole line considerations

Once the substation design was finalized, the power supply was reviewed as part of this design to ensure proper sequencing of installation. As can be seen in Illustration 12 above, the existing substation power line is directly above one of the proposed transformers. Since this substation needs to remain in service for the duration of the construction portion of the project for the mine to continue operating, removing the power line altogether is not an option. It is already known that not all transformers are required immediately to remove the ex. substation and the 4th transformer is provisional for future mine expansion. In knowing this, the area under the existing power line can be set as the provisional bay. The substation in ground civil work can be constructed in its entirety and the gantry can be done as shown in Illustration 17.

Illustration 17 – Construction phasing



Using a down day, the power line feed the existing transformer can be removed, the missing girders at the provisional transformer can be installed and power can be re fed to everything from the high bus. Being able to visualize this advance is large advantage in planning for a successful outage limiting down time to a day vs the potential alternative of multiple days which has a significant cost impact on project feasibility.

3.0 Conclusion

In summary, the use of 3D technology available can greatly improve the process for substation design. Although it is showcased through out this report for a brownfield application (retrofitting into existing), it can also be beneficial in a greenfield application (new design).

This report shows that with proper understanding of relevant codes and knowledge of site-specific requirements a step-by-step approach can be taken to model any substation working from the transformer outwards. Thus, allowing for high-level layout options to be evaluated quickly in multi transformer scenarios. The layout and proper spacing requirements can then be set so that additional equipment can be added and the outer limits required determined. With this in place, any optimization to the overall footprint can occur. It has also proven that 3D modelling is an effective tool for providing accurate material take-offs which are used not only for trade off studies as was the case in this report, but overall construction cost estimation. Along with the added benefit of being able to pre determine any existing site interferences so the construction can occur safely and sequencing can be predetermined leading to more efficient and shorter shutdowns.

4.0 References

1. Ontario Electrical Safety Code (OESC) 29th Edition – 2024

2. FM Property Loss Prevention Data Sheets (5-4 – Transformers), https://www.fm.com/resources/fm-data-sheets

5.0 Appendices

Appendix A

OESC Table 30-32

Table 30
Minimum clearances for bus support and rigid conductors
(See Rule 36-108.)

	Minimum air gap distance, mm		
	From live parts to adjacent surfaces other than insulation and bases of bare conductor supports*	Between live parts† (not centre-to-centre)	
Maximum system voltage, kV	**Indoor and outdoor**	**Indoor**	**Outdoor**
Not exceeding 7.5	190	150	180
15	260	230	305
25	305	330	380
		Indoor and outdoor	
34.5	380	460	
46	460	530	
69	740	790	
120	1200	1350	
161	1560	1830	
230	2300	2670	

** For ungrounded systems, the maximum system voltage is the phase-to-phase voltage, and for grounded systems, it is the phase-to-ground voltage.*
† For all systems, the maximum system voltage is the phase-to-phase voltage.

Table 31
Minimum horizontal separations of line conductors attached to the same supporting structure
(See Rule 36-108.)

Maximum system voltage*, kV	Minimum separation of conductors for span 50 m or less†, mm
Not exceeding 5.0	300
7.5	325
15	400
25	500
34.5	600
46	700
69	950

** For all systems, the maximum system voltage is the phase-to-phase voltage.*
† For voltages greater than 69 kV and for spans greater than 50 m, the requirements of CSA C22.3 No. 1 shall apply.

Table 32
Vertical isolation of unguarded live parts
(See Rule 36-110 and Appendix B.)

Maximum system voltage*, kV	**Minimum separation from ground, m**			
	Areas accessible to pedestrians only			**Areas likely to be travelled by vehicles**
	Indoors	**Outdoors**		
		Light snow area†	**Heavy snow area†**	
Not exceeding 15	2.9	3.4	4.0	4.7
25	3.2	3.7	4.3	5.2
34.5	3.2	3.7	4.3	5.2
46	3.2	3.7	4.3	5.2
69	3.5	4.0	4.6	5.5
120	4.0	4.5	5.1	6.0
161	4.4	4.9	5.5	6.4
230	4.8	5.3	5.9	6.8

* *For ungrounded systems, the maximum system voltage is the phase-to-phase voltage, and for grounded systems, it is the phase-to-ground voltage.*

† *See Appendix B.*

Note: *Radial clearances from live parts shall be maintained in accordance with this Table where conductors overhang the edge of a building or structure, including any protuberances.*

Amend cross-references in CE Code Table 33 as follows:

Table 33
Horizontal clearances from adjacent structures (including protuberances)*
(See Rules 26-302, 36-110, and *75-708*, and Appendix B.)

Maximum system voltage†, kV	**Clearance, m**
Not exceeding 46.0	3
69	3.7

* *See Appendix B.*

† *For ungrounded systems, the maximum system voltage is the phase-to-phase voltage, and for grounded systems, it is the phase-to-ground voltage.*

Appendix B

FM Global Property Loss Prevention data Sheet

Table 7. Transformer Fire Exposure to Noncombustible Building Roof Where Separation from Wall is Based on a 3-hour Fire Barrier or Water Spray Protection

Liquid Type	*Maximum Liquid Volume gal (m^3)*	*Building Height, ft (m)*	*W (see Fig. 5) ft (m)*
Non-Approved transformer fluid	<1000 (3.8)	Any	Not exposed
	Any	≥50 (15)	Not exposed
	1000-5000 (3.8-19)	≥25 (7.5)	Not exposed
		<25 (7.5)	15 (4.5)
	>5000 (19)	<50 (15)	25 (7.5)

2.3.1.1.3 Provide a Class A rating for external fire resistance over at least the section of the roof, if any, that is determined to be exposed per 2.3.1.1.2 and Table 7. (See Data Sheet 1-42, *MFL Limiting Factors*, for description of Class A roof installations).

2.3.1.2 Exposure Protection from Roof-Mounted Transformers

2.3.1.2.1 If roof-top transformers use non-FM Approved fluids, locate the transformer away from walls of adjoining buildings with higher roofs in accordance with Section 2.3.1.1.

2.3.1.2.2 If roof-top transformers use non-FM Approved fluids, provide a Class A roof covering for at least the horizontal distance from the transformer specified for noncombustible construction in Table 5. (See Data Sheet 1-42, *MFL Limiting Factors*, for description of Class A roof installations.)

2.3.1.3 Exposure Protection for Outdoor Transformers and Other Equipment

To protect transformers and other important equipment against exposure fire from adjacent transformers, provide separation, a fire barrier, or a water spray system in accordance with any one of the following three alternatives:

2.3.1.3.1 Provide separation distances for exposed transformers and other critical equipment in accordance with Table 8. Distances in Table 8 refer to the closest edge of containment.

Table 8. Minimum Separation Distances Between Adjacent Transformers

Liquid Type	*FM Approved Transformer?*	*Liquid Volume, gal (m^3)*	*Distance, ft (m)*
FM Approved Transformer Fluid	Yes	N/A	3 (0.9)
	No	≤10000 (38)	5 (1.5)
		>10000 (38)	25 (7.6)
Non-Approved Transformer Fluid	N/A	<500 (1.9)	5 (1.5)
		≤5000 (19)	25 (7.6)
		>5000 (19)	50 (15.2)

2.3.1.3.2 Where the separation distances in Table 8 cannot be met, provide 2-hour fire-rated barriers between transformers as shown in Figure 6 and as follows:

A. Extend barriers 1 ft (0.3 m) vertically and 2 ft (0.6 m) horizontally beyond transformer components that could be pressurized as the result of an electrical fault, including bushings, pressure-relief vents, radiators, and tap changer enclosures.

B. Use of concrete block or reinforced concrete construction is preferred.

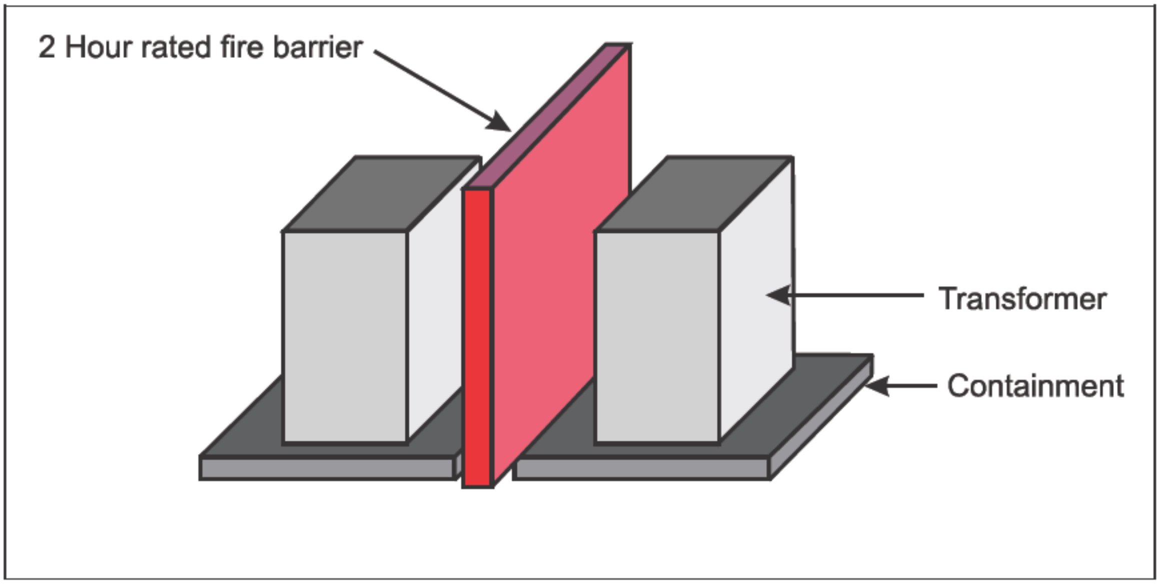


Fig. 6. Fire barriers for multiple outdoor transformers

2.3.1.3.3 For installations where the separation distances between transformers in Table 8 are not met and barriers are not provided, install water spray protection on each transformer in accordance with Section 2.3.2.

2.3.1.4 Spill Containment and Emergency Drainage

Spill containment requirements for environmental protection and related regulations are outside the scope of this data sheet.

2.3.1.4.1 Provide outdoor liquid-filled transformers with spill containment if accidental release of the transformer fluid could expose a main building or adjacent equipment or storage to fire damage.

2.3.1.4.2 Design the spill containment system in accordance with IEEE STD 980 (*Guide for Containment and Control of Oil Spills in Substations*) or equivalent standard.

2.3.1.4.3 Where water spray protection is provided for a transformer, provide containment with a capacity of at least a 60-minute discharge of fire hoses (500 gpm) plus the flow of the water spray system. Size the drainage and containment assuming adjacent water spray systems on both sides of an exposing transformer will operate simultaneously with the original activating system. Provide drainage in accordance with Data Sheet 7-83, *Drainage Systems for Flammable Liquids*.

2.3.1.4.4 Provide a system for removal of rainwater from the containment area.

2.3.1.4.5 Extend the containment perimeter at least 5 ft (1.5 m) beyond fluid-containing components, including any external coolers, for transformers with up to 1,000 gal (3.8 m^3); and 8 ft (2.4 m) for transformers with more than 1,000 gal (3.8 m^3).

2.3.2 Active Protection for Outdoor Transformers

2.3.2.1 If automatic water spray exposure sprinkler protection is provided for outdoor transformers, design the system as follows:

A. Provide a discharge density of 0.3 gpm/ft^2 (12 mm/min) over transformer surfaces, except areas under the transformer, with equipment designed in accordance with Data Sheet 4-1N, *Water Spray Fixed Systems*, and Data Sheet 2-0, *Installation of Sprinkler Systems*.

B. Refer to Figures 7 and 8 for typical nozzle layouts.

C. Locate components of the water spray system (piping, spray nozzles, etc.) a minimum of 18 in. (45 cm) from the transformer.

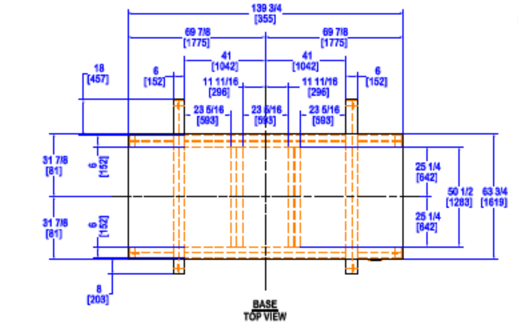
D. Do not locate piping over the top of the transformer or tank relief vents.

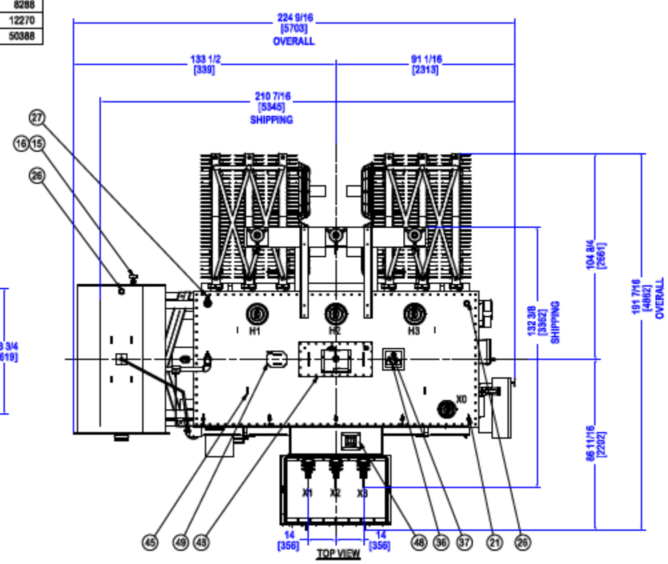
Appendix C

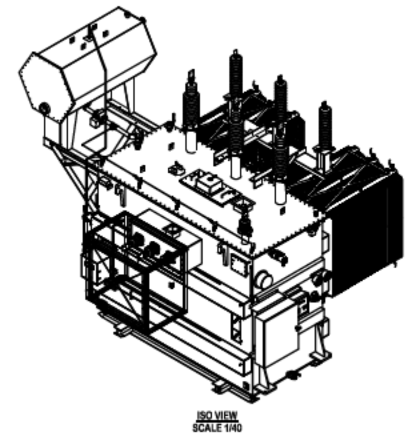
Typical 69/13kV 25MVA Transformer Outline

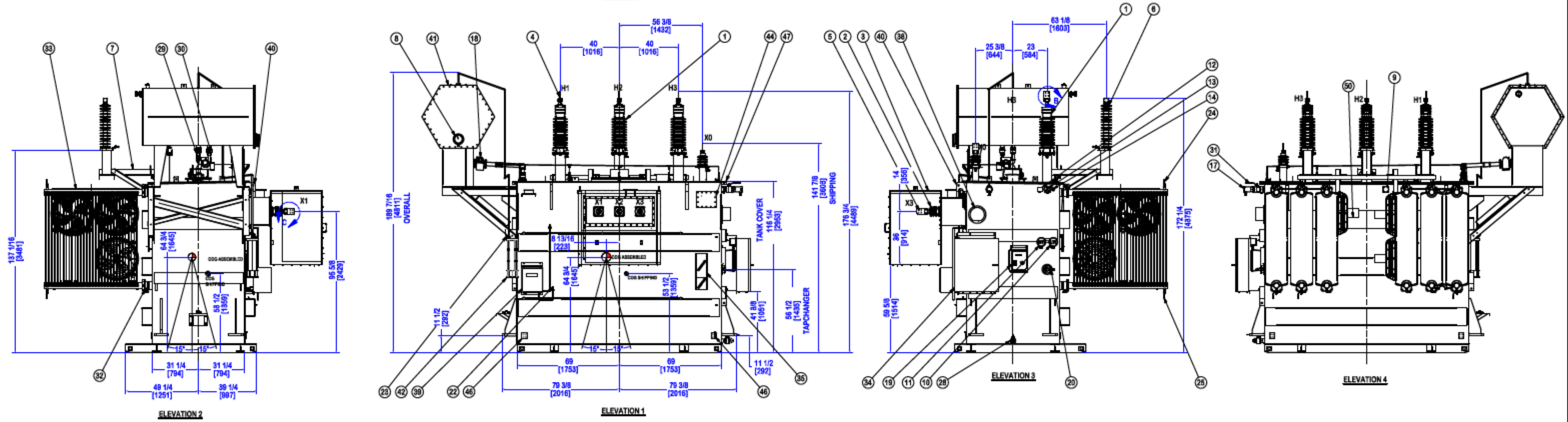
SHIPPING WEIGHT		
PARTS REMOVED	LB	KG
HV BUSHINGS	405	184
HV ARRESTERS	123	56
LV BOX	461	210
RADIATORS	5806	2634
CONSERVATOR	666	303
LUMINOL TRI 388 GAL. 1763.7 L.	3928	1782
TOTAL - REMOVED PARTS	11389	5166
TOTAL - SHIPPING WEIGHT	99693	45222
TOTAL - ASSEMBLIED UNIT	111082	50388

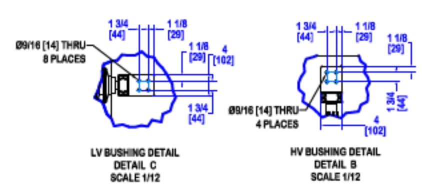
APPROXIMATE WEIGHT		LB	KG
	CORE & COIL	65762	29830
	TANK & FITTINGS	18271	8288
VOLTESSO35	3145 GALS. 14298 L.	27049	12270
	TOTAL	111082	50388











SCALE: NTS	DRAWN BY: DESIGNER	DATE:	REV.
SHEET: 1 OF 1	APPROVED BY: APPROVED	DATE:	PART NAME

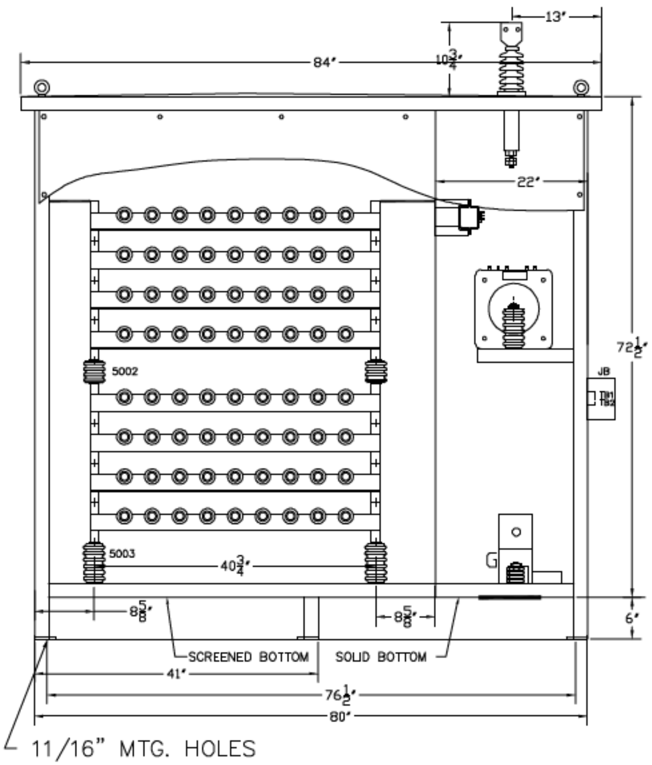
TITLE:

TYPICAL 69/13.8kV 25MVA TRANSFORMER OUTLINE

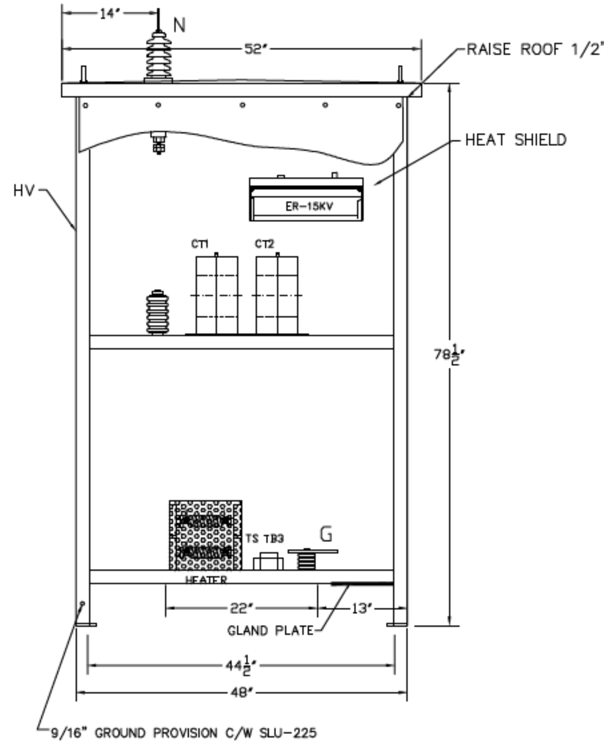
DRAWING NO.

Appendix D

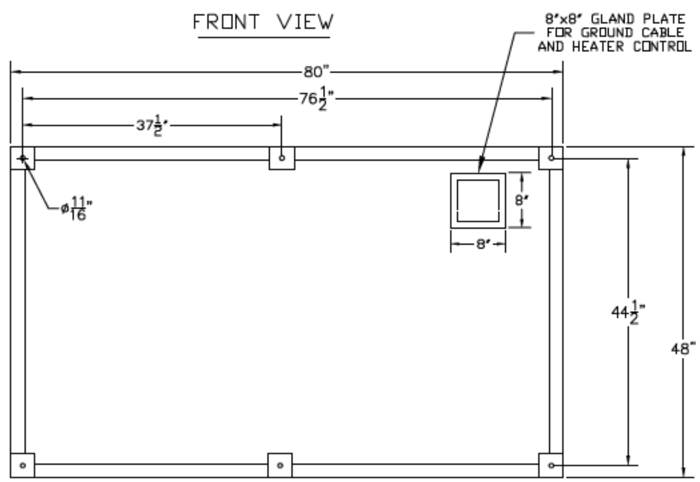
Typical 13.8kV Neutral Grounding Resistor (NGR) Outline



FRONT VIEW



END VIEW - RIGHT SIDE

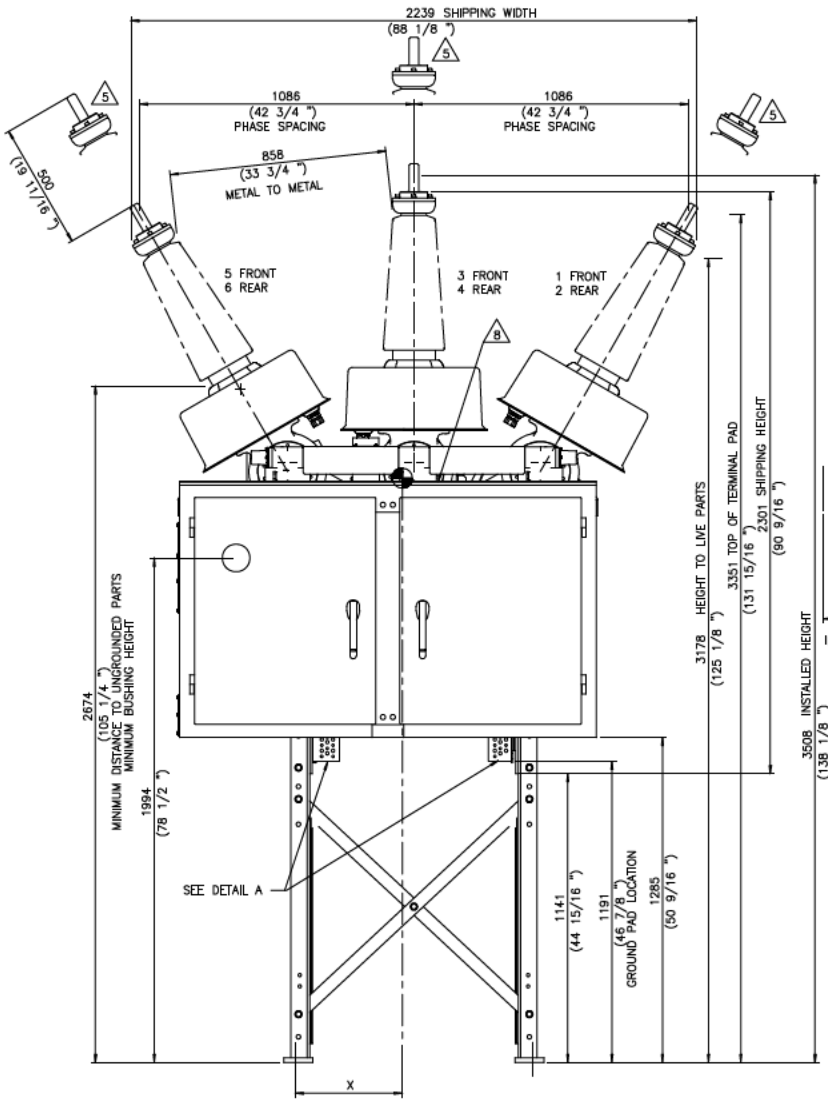


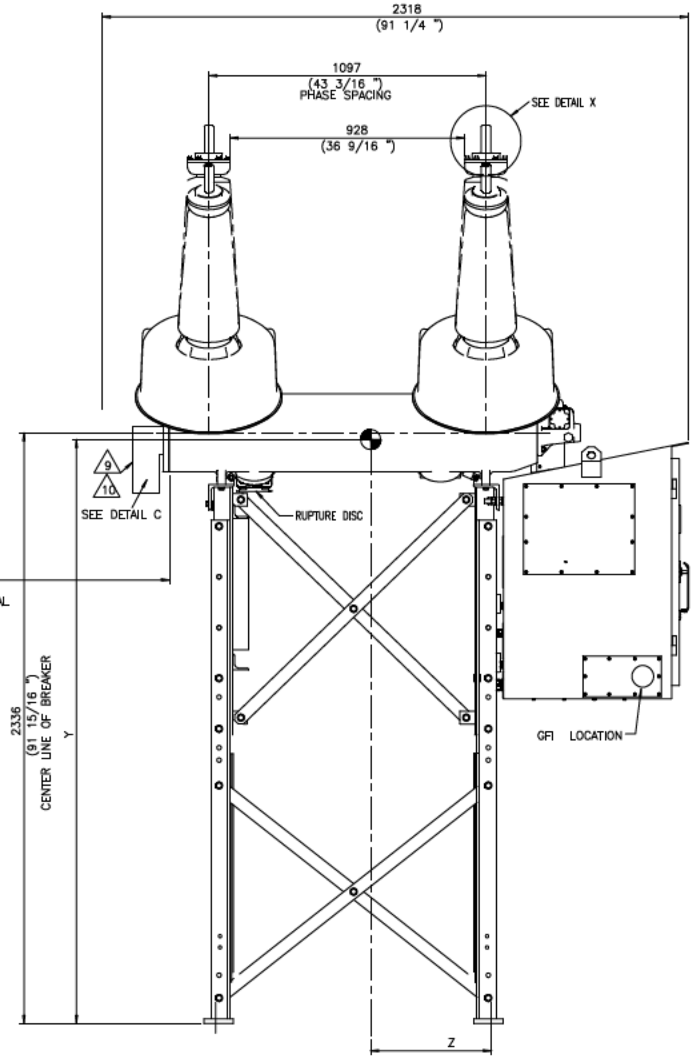
MOUNTING DETAILS

TITLE			DATE
TYPICAL NEUTRAL GROUNDING RESISTOR OUTLINE			
	TYPE	DRAWING NUMBER	REV. 1

Appendix E

Typical 69kV Circuit Breaker Outline





CENTER OF GRAVITY (mm)		
	AS INSTALLED	AS SHIPPED
X	424	424
Y	2310	1169
Z	478	478

NOTES:

1. CONDUIT ENTRANCE (REMOVEABLE PLATE)
2. COLOR OF CABINET AND BUSHINGS WILL BE ANSI70 GRAY
3. BUSHING CREEP = 72" (1829mm)
4. INDICATES CENTER OF GRAVITY
5. ALLOW 500mm ELEVATION ABOVE BUSHINGS FOR BUSHING REMOVAL.
6. BUSHING TOP TERMINALS SHIPPED SEPARATELY.
7. USE ONLY FLEXIBLE CONNECTORS FOR CONNECTION TO BUSHING TERMINALS. MAXIMUM LINE PULL SHOULD NOT EXCEED 150 LBS./ 667 N
8. LOCATION FOR TRAVEL ANANYZER
9. DENSITY MONITOR LOCATION
10. PRESSURE GAUGE LOCATION

FOUNDATION LOADS

(INCLUDES OPERATIONAL LOADS, 150 LBS./667 N LINE LOADS AND EITHER 0.5G DYNAMIC OR 90 MPH/145KMH WIND LOADS)

OVERTURN MOMENT	62,274 FT-LBS / 87,143 Nm
TOTAL SHEAR	9,249 LBS / 41,143N
TOTAL COMPRESSION	10,323 LBS / 45,917N

MAXIMUM ANCHOR BOLT LOADS

TENSION	7,926 / 35,257N
SHEAR	2,312 LBS / 10,286 N
PAD COMPRESSION	10,028 LBS / 44,605 N

FOUNDATION & ANCHOR BOLT LOADS PER ED 3.1.1040

RATING	TYPE	72PM40-20C
	MAX VOLTAGE KV	72.5
	CONTINUOUS CURRENT AMPS	2000
	SHORT CIRCUIT KA	40
	BASIC IMPULSE LEVEL KV	350
	WEIGHT WITHOUT GAS LB/KG	4,203/1,906
	SF6 GAS PER BREAKER LB/KG	22/10

ALL DIMENSIONS IN MILLIMETERS UNLESS NOTED

TYPICAL BREAKER OUTLINE

SCALE NTS

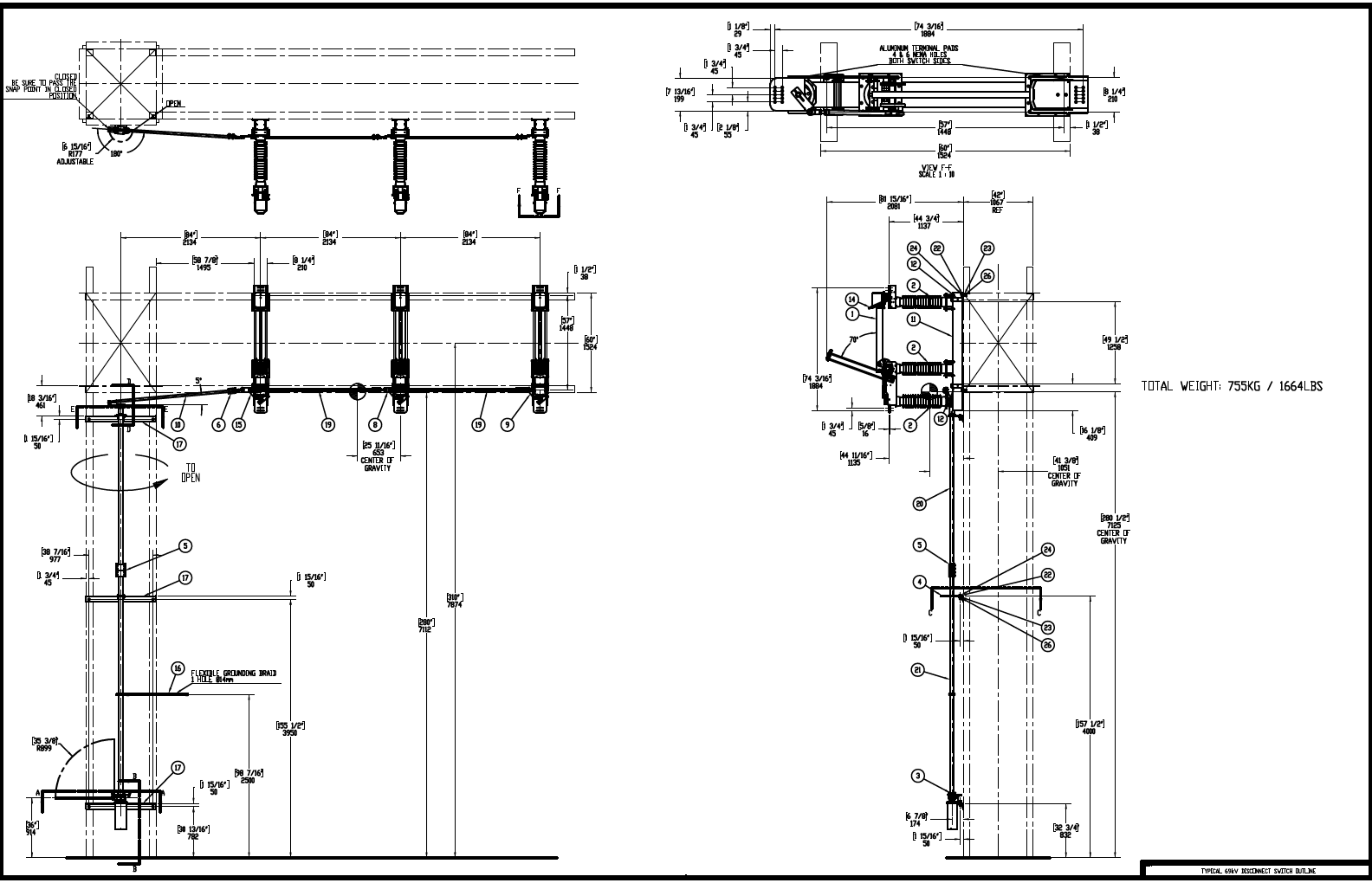
ASSY. DWG.

DWN | CHKD | APPD

REV. 01

Appendix F

Typical 69kV Disconnect Switch Outline



TOTAL WEIGHT: 755KG / 1664LBS
VIEW F-F
SCALE 1 : 10
ALUMINUM TERMINAL PADS
4 & 6 NEMA HOLES
BOTH SWITCH SIDES
CLOSED
BE SURE TO PASS THE
SNAP POINT IN CLOSED
POSITION
OPEN
ADJUSTABLE
TO
OPEN
CENTER OF
GRAVITY
FLEXIBLE GROUNDING BRAID
1 HOLE Ø14mm
TYPICAL 69kV DISCONNECT SWITCH OUTLINE