Whitepaper

Modular Substation Cable Termination Design

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Abstract

The methods for cable penetrations into modular industrial substations are summarized. The requirements for structural and environmental integrity, grounding, fire protection and ease of expansion for a cable termination system are discussed. Current methods of installation are compared to using a cable transit design for installing and terminating cables in electrical substations.

Index Terms – cable termination, modular substation, cable transit.

Introduction

Modular substations are becoming the preferred approach for installing electrical and control equipment in industrial facilities. The ability to prefabricate a building, pre-install both electrical and control equipment and the ability to pre-commission equipment prior to the installation helps to reduce on-site construction installation costs. This is particularly advantageous in remote project locations where the cost of labor can be very high.

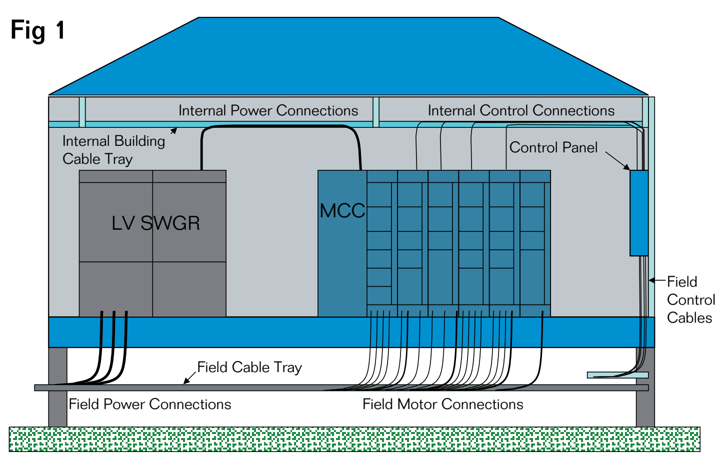
The on-site termination of conductors and cables into equipment can often be an issue. The equipment layout, the design of the modular building skid base frame, the number of terminations and the termination method can all influence the speed and ease of installation. Choosing the wrong penetration approach can compromise the environmental integrity of the building and equipment, significantly increase installation cost and complicate the ability to install cables and conductors in the future. This has a direct impact on the cost of ownership over the life of the asset.

Modular substation fundamentals

A typical modular substation consists of a steel frame skid base supporting a prefabricated insulated panel constructed building. The dimensions of the building can vary and are usually determined by the amount of equipment installed and the transportation logistics for a project. It is common to see substation buildings with dimensions in
excess of 30 meters in length, 7 meters wide and 6 meters high for domestic onshore projects. If the equipment layout dictates a larger building footprint, often the building will be split in two for transport to site.

Interconnecting wiring between equipment is usually done in one of two ways. If the substation is constructed on raised piles, and the wiring connections are internal to the substation, the conduits or cables are run overhead within the substation. External field cable connections are then terminated into the floor of the substation directly into the equipment item. This approach has the advantage of minimizing the height of the building and allowing for convenient access for workers to terminate field cables. Fig. 1 illustrates this concept.

Fig 1



Terminating cables in substations

There are a number of challenges associated with terminating cables in a modular substation. The first being the number of field terminations. In a medium sized industrial substation servicing a large number of motor interconnections, there may be up to 300 or more power and control cable terminations. The terminations must be coordinated with the location of the electrical and control equipment and the skid frame steel members supporting the building. Often, a large number of cables must be terminated in a very limited area leading to cable and connector congestion which can impact worker productivity.

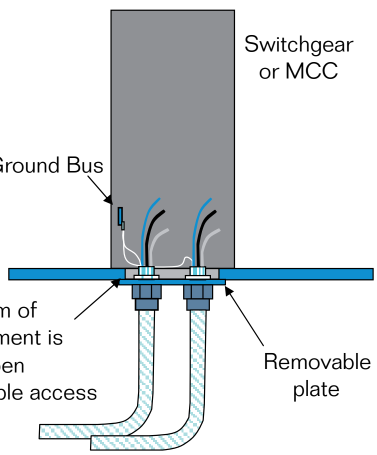
Another challenge associated with terminating field cables is maintaining the environmental integrity of the equipment and the substation building envelope. This requires that the termination method maintain a vapor-tight weather barrier with a suitable insulation 'R' factor value to avoid condensation within the equipment and the building envelope. The cable termination method should also provide a fire resistant barrier in the unlikely event of a fire.

The cable termination method must accommodate a variety of cable construction configurations and wiring methods. Cable diameters can vary with some control conductors with diameters of 5mm or less to 3/C 500MCM armored power cables which may have diameters of 100mm or more. In each case, the cable must be properly secured and grounded in accordance with the local electrical installation codes and requirements.

One often overlooked aspect of the cable termination method is the ability to add cables in the future. The flexibility to easily add additional cable can pay dividends even during the initial installation when design modifications are made late in the installation phase of a project.

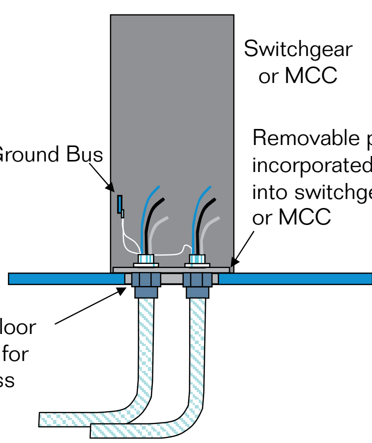
Traditional cable termination options

Fig 2



Cable Termination into Floor of Substation

Fig 3



Cable Termination directly into Switchgear/MCC

There are several cable termination methods currently used to terminate conductors into industrial substations. Some projects prefer that all cables are terminated into the top of electrical and control equipment mounted inside the building. A cable transit barrier is often used to allow cables to pass through an exterior wall.

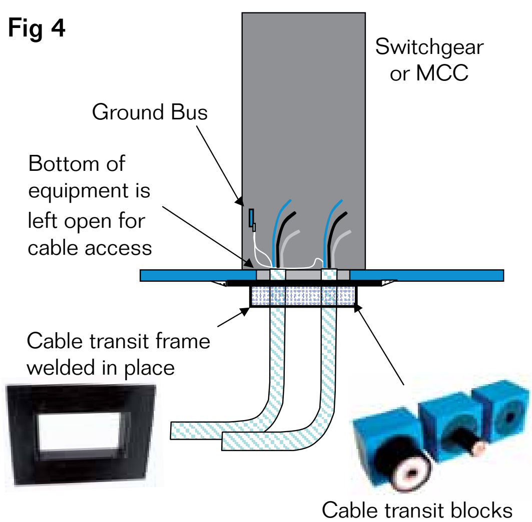
Fig. 2 illustrates a method where cables are terminated into the floor of a substation. A ¼" steel removable panel is used to facilitate the pre-drilling of holes for the cable connectors prior to the field installation. This helps to improve construction productivity by allowing the majority of the cable connector entry holes to be drilled in a shop environment. Once the connector plate is fastened in place, drilling becomes more difficult and time consuming. There is also the potential for metal filings to contaminate the switchgear cable termination compartment. Each connector hole must also be de-burred to prevent the conductor insulation from being damaged when the cable conductors are pulled into place.

A second option for terminating cables is illustrated in Fig. 3. A section of the floor is removed and the cable is terminated directly into the floor mounted equipment. Some equipment, such as low voltage motor control centers (MCCs) incorporate a removable plate to facilitate the punching of holes for cable connectors. The removable plate is usually constructed of sheet metal steel and is easily punched using a hydraulic punch.

The primary disadvantage to this termination method is that large sections of the floor must often be removed to gain access to the underside of the equipment. This may compromise the structural integrity of the floor and building envelope. Future cable entry is also difficult as access to the plate must be provided both above and below the cable connector location. In certain cases, if the plate is not of sufficient thickness, large cables can deform the plate, further compromising the integrity of the installation.

Improved cable termination option using a cable transit system

Fig 4



Cable Transit Installation for Switchgear/MCC Entry

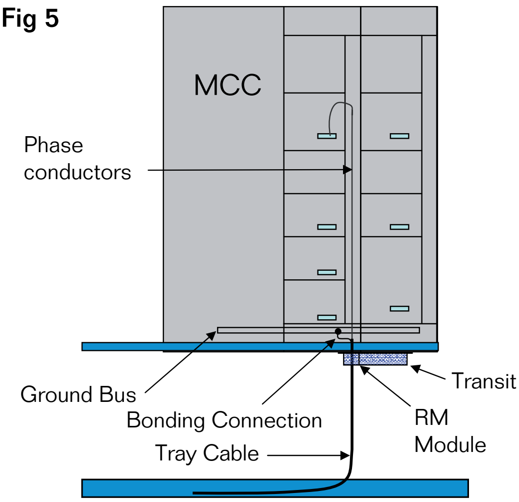
A third option for terminating cables into a substation is to use a transit entry frame. Fig. 4 illustrates a transit entry installation.

The transit frame is welded or bolted to the substation floor at strategic locations where cables will be terminated. The cables are then pulled into place through the transit frames and then sealed using Multidiameter™ cable transit blocks and a mechanical compression wedge. The cable transit system provides cable retention and provides an environmental, fire resistant and gas tight seal to the equipment and building enclosure.

There are several advantages to using a cable transit for cable entry into a substation. The first being efficiency. A cable transit allows multiple cables to be pulled at the same time through the transit opening. The large opening eliminates the potential damage to the conductor insulation during installation. Secondly, the transit frame maintains the structural and environmental seal integrity of the floor and allows for a high density and capital efficient installation of cables within a very small footprint. Also, future expansion capacity is provided for each transit via unused cable blocks which can be easily removed and reinstalled for future cable installation.

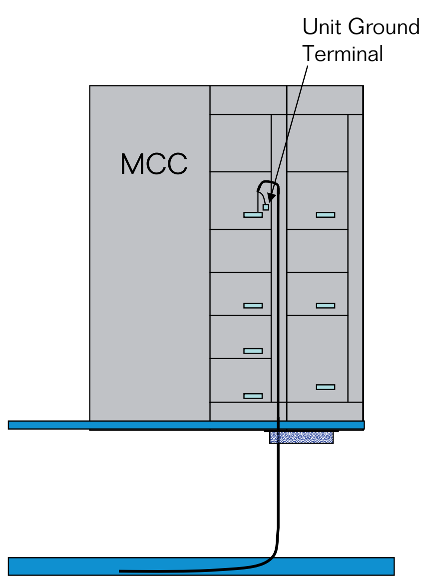
Another significant advantage of sealing cables with a cable transit system is the additional room below the building floor and equipment that is provided by the extension of the transit frame. This depth may be customized to a depth equal to the height of the structural steel, and has a standard depth of 60mm. This additional working space assists with the restrictive bend radius of larger armored cables and allows for proper cable alignment with equipment configuration.

Fig 5



Option 1 for Grounding Tray Cable

Fig 6



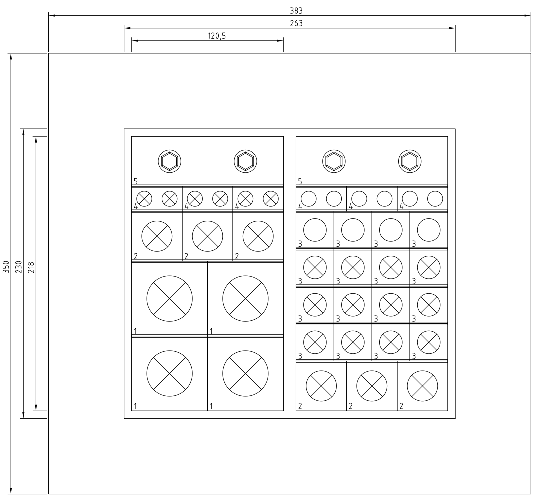
Option 2 for Grounding Tray Cable

Equipment Grounding for Tray Cables

There are two methods for terminating the bonding conductor of a tray cable using a cable transit system. The first involves connecting the bonding conductor directly to the ground bus of a switchgear or MCC. The PVC sheath is stripped back to the transit entry location and the bonding conductor is removed and connected to the equipment ground bus. The phase conductors then continue to the termination point in the switchgear or MCC. This is very similar to what occurs when a standard cable connector is used to terminate a conductor.
Fig. 5 illustrates this method of bonding.

A second and less labor intensive option exists for grounding tray cables in MCCs. Some MCC manufacturers provide the option of a "unit" ground connection at the MCC bucket rather than on the equipment ground bus. This reduces the amount of cable sheath that must be stripped back in order to connect the bonding conductor to the equipment ground bus. This has the advantage of keeping the phase and bonding conductors together as an assembly within the equipment and breaking out the bonding conductor closer to where the phase conductor terminations actually occur. Fig. 6 illustrates this method of bonding.

Fig 7



Engineering Drawing of Cable Transit System

Work process

To use a cable transit system to its fullest advantage, an understanding of the work process from design through final installation is required.

A. Engineering

The use of a cable transit for terminating cables into a substation requires pre-planning. The location of electrical and control equipment must be coordinated with the structural steel base to insure that transit frames of an adequate size and dimension can be installed without interference from support steel in the steel base. If possible, a standardized frame size helps to simplify the design and installation process.

During the design phase, as cables are identified, they are assigned to a transit frame. This information can be integrated into the cable schedule or often dedicated software is used to create detailed transit schedules. Once the transit schedules are complete, the bill of material can be generated for both the substation fabricator and field installation contractor.

Fig. 7 illustrates a typical engineering drawing produced by Roxtec RTM Software for an MCC transit with capacity for 43 cables of various diameters installed within a 23cm x 26cm window. The flexibility of this system allows cable and pipe sizes ranging from 3 mm (.118 in) to 99 mm (3.898 in) to be sealed within the transit frames.

B. Fabrication

Once the size of the cable transit and the locations are identified, the transit frames can be purchased and shipped to the fabricator for installation. The transit frames are mounted into the wall or floor by bolting or welding and then temporarily sealed for transportation to site.

Fig 8

C. Site Installation

After the modular substation is shipped to site and set in place, installation of the field conductors can begin. The site installation contractor will install interconnecting cables from source to destination via the cable transit openings identified on the cable schedule. The large opening provided by the cable transit helps the installer pull the cable into place and minimizes any damage to the conductor insulation. When all cables for a cable transit are installed, the cables are secured and sealed using the cable transit blocks with stayplates and a mechanical compression wedge. The cable transit drawings help to identify what cables should be placed where and what size cable block should be used. The transit schedules also record how much spare capacity is available in each cable transit for future growth. Cables can be easily added without cutting or drilling additional holes, simply by loosening the compression wedge.

Training is essential to help field installers understand the transit termination concept. Training can be provided using on-site training services or by installation videos that provide step-by-step instructions. Once the installer has observed and installed the transit blocks for one transit installation, subsequent transit installations are easily completed. Figure 8 illustrates the installation of a transit barrier in a modular substation application.

Conclusion

There are several advantages to using a cable transit for installing and terminating cables in industrial substations. It provides a standardized design with the flexibility to terminate a variety of different sizes and cable constructions. The ease of installation helps to reduce labor costs and minimize the potential for insulation damage. The structural and environmental integrity of the wall or floor penetration is maintained providing an insulated, vapor-tight and fire-stop barrier and cables can be easily added in the future. Cable transits are a viable alternative for terminating cables into industrial substations.

H. Vita

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Roxtec International AB, the parent of Roxtec, Inc. was established in 1990 and is the global leader in modular-based cable and pipe sealing systems. Roxtec maintains more than 250 registered tests and approvals and serves the oil & gas, telecom, marine, industrial and OEM industries in more than 70 markets around the globe. Additional information about the company, products, applications and engineering data may be found by visiting www.roxtec.com.

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