



Advantages of modular unit substations

Overview

Substations are a critical part of the electrical generation, transmission, and distribution system designed to help transform voltages and perform several other essential functions including protection, monitoring, and switching.

Modular substations offer many advantages to conventional substations including saving space and installation time while enhancing safety and aesthetics. This paper outlines the benefits of modular substation solutions.



New Eaton modular integrated transportable substation (MITS) in front of open air substation to be retired shown behind.

Background

Today, unit substations help serve loads in an industrial plant, campus, or urban areas fed with non-standard voltage ratings or a limited capacity to additional remote loads. In many cases, electric power may flow through several substations at different voltage levels before reaching the consumer.

To enhance power reliability and safety for these consumers, unit substations commonly incorporate a high side breaker for protection, a load tap changer (LTC) for voltage regulation, and circuit protection or recloser solutions for feeder and transformer protection.

Despite decades of successful service, a large portion of these installed unit substations are reaching the end of operational life or quickly approaching capacity limits, which presents major maintenance issues, replacement challenges, and safety concerns.

Additionally, many utilities are striving to modernize infrastructure to better accommodate non-standard voltages and growing demand. Because the overhaul of unit substation networks can be a costly process, localized units can be used as a cost-effective solution.



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The challenge

The upkeep of unit substations is vitally important, as failure or malfunction can produce serious system disturbances and outages. Because most units are located in mature urban areas, failure can also pose significant public risk and fire safety concerns.

Components approaching more than 30 years of operation present numerous modernization challenges. The difficult task of sourcing replacement parts can make it expensive to repair units and lengthens response time following a failure. There are few technicians in the marketplace with experience maintaining vintage substation components, which also makes it hard to obtain effective support.

Three traditional solutions to extend the life of aging unit substations or increase transmission capacity include voltage conversion, continuous maintenance, or complete replacement. However, all three of these solutions present a number of unique challenges that can greatly complicate projects.

1. Land acquisition and accessibility

When replacing unit substations where land is costly, such as urban areas, the site must have room for expansion for load growth or planned transmission additions.

For voltage conversion, sufficient land area is required for installation of equipment with necessary clearances for electrical safety, which can be difficult in locations with tree line or building proximity. In addition, adequate space must be available for the accessibility to maintain or transport large apparatus such as transformers.

2. Environmental concern

The impact to the surrounding area of the substation must be considered, such as drainage, noise pollution, and road traffic impact. The potential for exposed high voltage components in urban areas can also create a challenge due to wildlife.

Some older transformers may also still contain polychlorinated biphenyls (PCBs) as a dielectric fluid. In the early 1970s, production and new uses of PCBs were banned due to adverse environmental impact and toxicity concerns. Most transformers with PCBs have already been replaced; however, if discovered, these units must be maintained with extreme caution and spill containment systems on all substations must adhere to the EPA's Spill Prevention, Containment, and Control (SPCC) guidelines.

3. Cost

Voltage conversion is a significant and frequently long-term project as aging or failing equipment is upgraded to work at both 4 kV and 15 kV voltage levels. During the process, cabling and insulators must also be replaced, adding to the cost.

Maintaining vintage unit substations can become an extremely expensive and labor-intensive task. The likelihood of component failure is increased as units exceed recommended operating life, and it can become a major drain on time and labor resources to locate vintage replacement parts.

4. Safety

Older unit substations were frequently designed with live front components at incoming or outgoing connection points. The danger and potential for electrical shock from these live front components necessitates costly fencing while creating a safety hazard for personnel, the public, and wildlife.

Additionally, completing unit substation construction in the field presents its own set of safety challenges. For example, important features such as molded rubber terminations can be compromised by dust, humidity, or liquid.

5. Aesthetics

Many unit substations are located in heavily populated urban areas. Traditional designs can become an eyesore because despite a relatively compact footprint, they require a large land parcel to accommodate fencing and other security measures.

Modular substation construction

Considering the challenges of replacing, converting, or maintaining unit substations, the application of a modular solution presents an alternative with many advantages. Compared to the ground-up construction of a conventional substation or the arduous process of voltage conversion, a modular approach can yield an array of benefits that helps to streamline the entire process, from design to installation, commissioning, and maintenance.

A modular substation solution is traditionally an electrical power distribution substation or any other grouping of electrical equipment that is assembled on a self-supporting structural base, integrated and tested in a factory environment to enable energizing upon delivery. Alternately, the equipment can be mounted on a Department of Transportation (D.O.T.) compliant trailer for mobile applications.

When paired with turnkey support from a trusted vendor, this modular and factory-assembled approach can provide the following benefits:

1. Streamlined logistics

When constructing a conventional unit substation, it is often necessary for a utility to work with separate design and construction personnel, and many different product manufacturers to complete a project.

With today's modern turnkey solutions, one vendor is able to manage all aspects of substation design and testing, component purchasing and delivery, as well as installation and commissioning. This also provides one single point of accountability for all system drawings and testing requirements.

By consolidating these processes, utilities can save valuable time and money while reducing project management complexity and the potential for miscommunication or conflict between vendors.

MODULAR SUBSTATION CONSTRUCTION SUPPORT



Jemez Mountains Electric Cooperative: installation of pad to house new transformer, new breaker installation, and MITS shown on right.

Turnkey installation and support from startup to commissioning

- High and low side connections
- Site preparation and construction of support structures
- Ground grid design and construction
- Delivery and unloading
- Acceptance testing of individual unit substation components:
 - Fluid testing, insulation, and contact resistance testing
 - Transformer turns ratio testing and winding resistance
 - High potential testing, power factor (Doble) tests, and IR scan
 - Verification of protection device settings
- Commissioning to ensure proper normal and emergency operations, often with warranty extension
- Testing of all transfer schemes, switching operations, remote operation via communications protocols, and customer-specific operating parameters
- Synchronizing to utility grid and on-site generation
- Site supervision of handling, installation, connection, and energizing
- Complete turnkey installation—training on equipment operations

2. Minimized costs

In addition to reducing logistical complexity, a turnkey approach to modular substation design can reduce project costs through the inclusion of factory assembly, wiring, and testing of the entire substation assembly.

Modular unit substations are inherently engineered to reduce the number of field connections necessary for on-board protection, control, and automation devices to minimize on-site labor.

The ability to test the entire unit prior to shipment reduces on-site labor while allowing for confident installation and quick commissioning. Factory assembly also eliminates construction delays due to environmental issues such as inclement weather or vandalism.

Working with a single vendor can also help unify project management to potentially reduce on-site installation and commissioning to as little as a single day. In combination with reductions to construction costs, the condensed project schedule can decrease the time workers spend commuting to worksites and the need for overnight lodging.

3. Reduced footprint and transportability

Modular unit substations are engineered to use as little space as possible while meeting a project's unique needs. The entire solution fits on a platform, making transportation and space requirements manageable. Structural base allows for assembled units to be lifted and transported, and easily relocated. This base also provides protection for interconnection power and control cabling and can be designed for on-board oil containment. If a mobile unit is required for fast deployment, the equipment can be mounted on a trailer base.

4. Enhanced safety and environmental benefits

A traditional overhead-fed substation often requires protective security features such as fencing to reduce potential exposure to exposed live parts. With modular unit substations, all equipment and connections are contained within tamperproof metal enclosures, with feeder elements installed underground, to provide a low-profile design capable of blending into the environment. This inherent low-profile design also contributes to enhanced aesthetics and customer acceptance, as well as easier permitting with local zoning authorities.

The enclosed design of a modular substation platform can also enhance personnel safety by using deadfront components whenever possible to shield personnel and the public from live electrical elements. The deadfront connections are in American National Standards Institute (ANSI) certified tamperproof locked cabinets that are safe and secure. This is a key feature that protects against unauthorized access, increasing the modular substations' overall safety and reliability. This feature also mitigates the need for perimeter fencing to lower costs.

Additionally, the platform protects shield-grounded medium voltage cable and copper grounds within the substation enclosure, making it less susceptible than competing systems to environmental, wildlife, theft, vandalism, and other damage.

5. Flexibility

An expandable design allows for a variety of equipment configurations to meet the requirements of various applications. To meet future needs, these modules can be quickly and easily connected together to form larger, more complex substations.

Because modular solutions are often much more compact than traditional unit substations, multiple units may be applied without the need for dramatic investment in real estate. Additionally, multiple skid assemblies can be configured to meet physical space constraints when systems are expanded.

This modular approach can help a company defer the cost of large system improvement projects by quickly allowing the addition of temporary power capacity, with the ability to support multiple projects across different locations over time.

Summary

With a large percentage of installed unit substations reaching the end of operating life and approaching capacity limits, utilities and other industries must make the difficult decision to continue costly maintenance, carry out a long-term voltage conversion, or completely replace existing installations.

However, all three viable solutions present their own set of unique challenges such as sourcing vintage parts, securing adequate land space, or allocating funds for major modernization.

Providing an alternative solution, turnkey and modular approach to unit substation construction can equate to lower costs, faster installations, aesthetically pleasing design, and most importantly a safe and secure system.

The flexible, expandable design allows a variety of equipment and system configurations for various applications, providing an effective, cost-efficient approach to unit substation modernization and replacement.

CASE STUDIES DEMONSTRATING THE VERSATILITY OF MODULAR SUBSTATIONS

1. Rapid expansion of transmission capacity

An electrical cooperative in the southwest U.S. recently applied a modular unit substation to support safer, reliable, and cost-effective power while rapidly meeting growing customer demand.

Faced with the challenge of quickly adding transmission capacity to meet the needs of an expanding industrial customer, the utility needed to expedite the construction of a new substation. After exploring the costs of a traditional approach, the utility discovered that an integrated power assembly was the best solution to reduce the engineering time required for the project to help maintain the customer's desired timeline, while factory assembly helped avoid construction and weather-related delays.

The modular substation design ultimately allowed the utility to meet its customer's evolving power requirements nearly three months faster than a traditional solution. The factory-designed and tested substation also helped decrease commissioning and installation complexity to minimize overall project costs.

2. Disaster response

When Hurricane Sandy left much of the upper East Coast devastated in 2012, a major utility was faced with restoring power to thousands of residents. Nearly six feet of water rendered a major substation so badly damaged by fire and salt water, the local authority soon recognized an alternative replacement would be needed.

The utility had recently purchased a modular unit substation to replace an aging installation in a different location and realized it was the ideal solution to help restore power quickly in the storm-impacted area.

A new substation can take many weeks or months to procure, install, commission, and energize. This modular solution was able to greatly minimize installation time because all the equipment was securely bolted in place on a skid and all interconnections between devices were already completed. Additionally, the components were already factory tested, which helped reduce commissioning time. All these factors meant the modular solution, once on-site, could be energized in a matter of days instead of weeks or months—helping quickly restore power and security to local residents.

3. Temporary load support

A Western electrical power utility is using three modular substation platforms to maximize the cost-effectiveness of natural gas extraction.

These configurations include a pad-mounted transformer, reclosers, and voltage regulators to enhance power reliability. With a transportable structural base, the utility can quickly relocate the substations to provide load support at new extraction sites. This capability allows the utility to redefine power systems flexibility by moving entire substations without the need for disassembly to drastically reduce labor and costs.

In addition, the units are engineered with deadfront components and ANSI-certified tamperproof, locked enclosures. This key feature protects against unauthorized access and environmental damage, increasing the modular substations' overall safety and reliability. The secure design also mitigates the need for perimeter fencing, helping to reduce material costs and labor when relocating extraction operations.



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