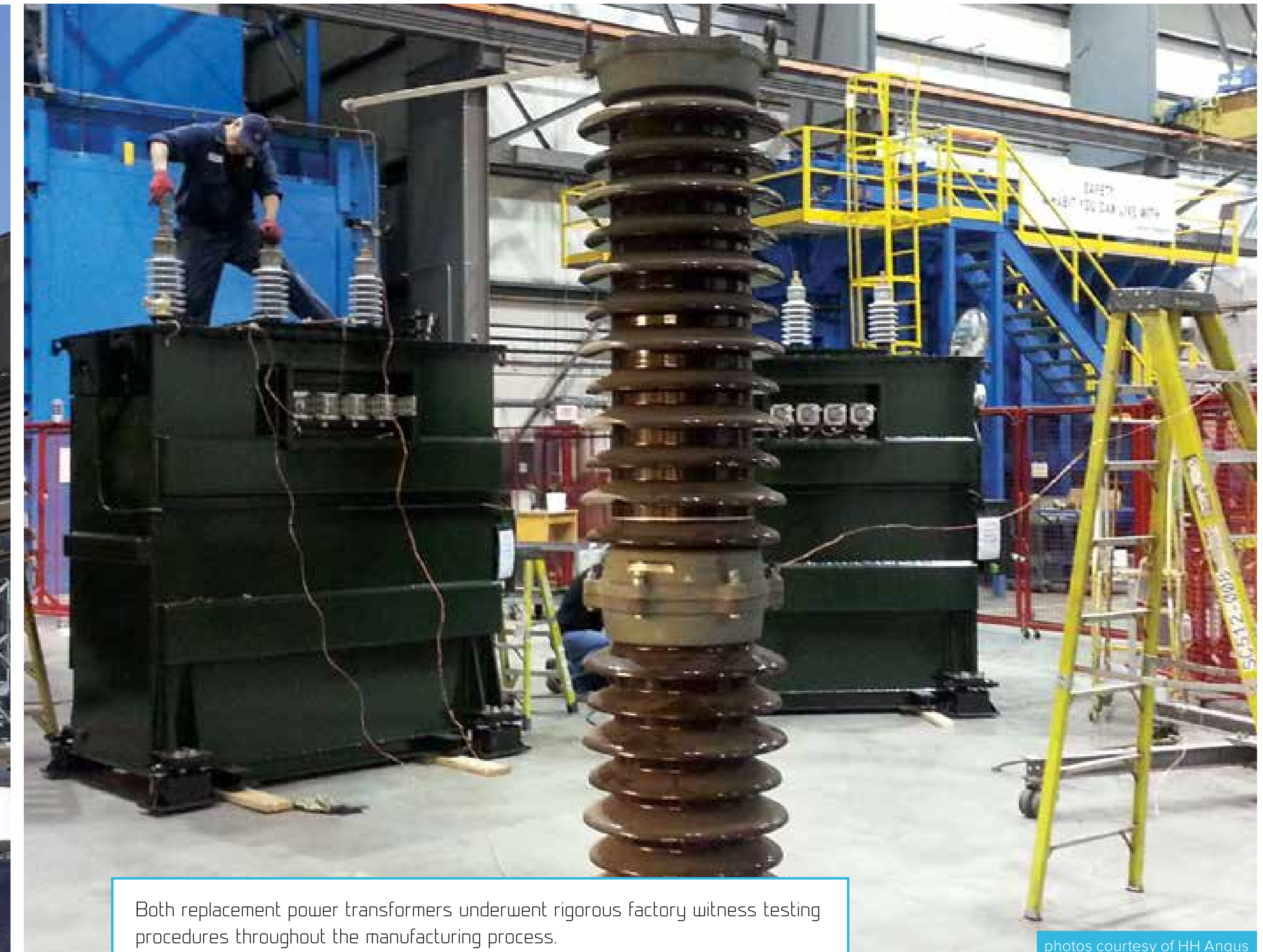
photo courtesy of Southlake Regional Health Centre

High Voltage Electrical Substations:

Infrastructure Renewal and Sustainable Design

Southlake Regional Health Centre undertakes an equipment replacement project in their High Voltage Electrical Substation, while remaining fully operational.

Throughout the project, a mobile crane was set-up multiple times to facilitate the removal of the existing transformers and the installation of the new transformers.



Both replacement power transformers underwent rigorous factory witness testing procedures throughout the manufacturing process.

photos courtesy of HH Angus

The recent increase in the frequency and severity of extreme weather, specifically on the Eastern Seaboard, has helped reinforce the importance of reliable electrical power distribution systems. Prolonged utility outages, experienced during Hurricane Sandy in 2012 and the Winter Ice Storm of 2013, resulted in hundreds of thousands of people being left without power for days and effectively shut down businesses, institutions and entire neighborhoods. The occurrence of even momentary outages can be extremely inconvenient and costly in a number of critical facilities, which include financial data centers, telecommunications facilities, hospitals and process based industries. While service interruptions in a utility`s network are largely uncontrollable, end users are responsible for maintaining the reliable operation of their facility`s power distribution system.

Large consumers of electricity typically receive one or more high voltage utility power services and have a customer-owned substation on their property. The substation consists of service entrance switchgear, which acts as a disconnecting point for the incoming utility services, and step-down transformers which transform the utility service to a lower voltage for transmission and distribution around the customer`s site. Most power distribution equipment has a long estimated service life (30+ years) and usually remains in service beyond this time. Given the capital costs associated with equipment replacement, aging infrastructure is often overlooked until a failure occurs. With manufacturing lead times for high voltage equipment in the neighborhood of twenty plus (20+) weeks, planned equipment replacement is necessary to reduce the risks of unexpected failures and associated outages. Drawing on a recent project at Southlake Regional Centre, this article will review how a high voltage electrical substation was upgraded in a manner that allowed a critical facility to remain fully operational, and examine sustainable design elements that were incorporated into the project.

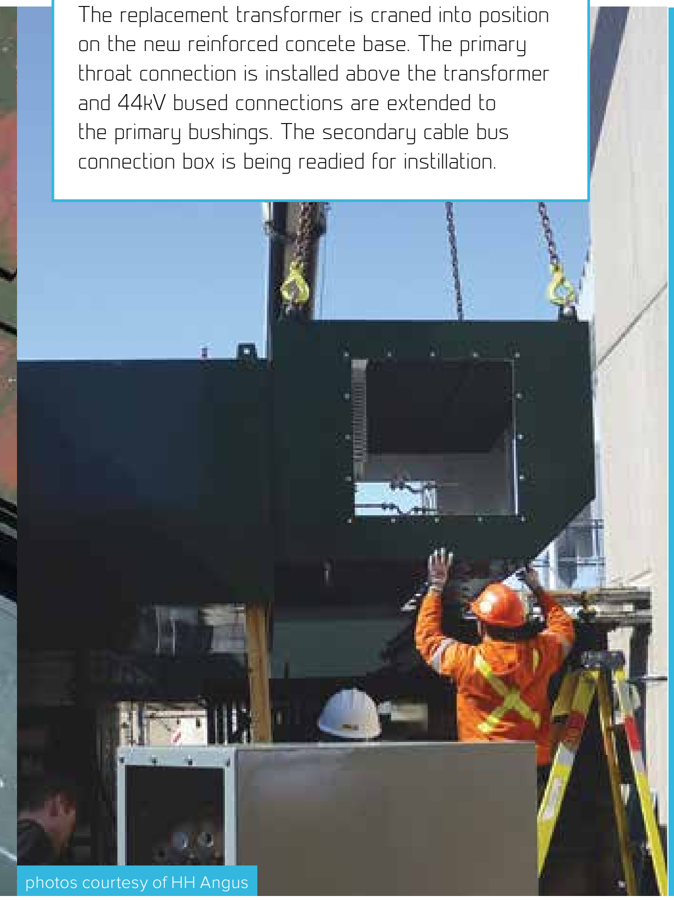
Southlake Regional Health Centre is a full-service, 400-patient bed hospital, located in Newmarket, Ontario. Providing critical healthcare services for York Region and Southern Simcoe County, Southlake accommodates more than 90,000 visits to the Emergency Department, 22,000 in-patient admissions, and 600,000 out-patient visits each year. The site receives a 44,000 Volt (44kV) utility service from Newmarket Hydro and has a dedicated outdoor substation which transforms the incoming service down to 600/347V, which feeds the hospital's central plant and is distributed throughout the campus. The existing substation consisted of 44kV service entrance switchgear, two 3000/4000kVA (ONAN/ONAF) oil filled power transformers and individual runs of 4000A, ventilated bus duct. With the installation dating back to the early 1970s, elements of the forty-plus year old substation were showing signs of deterioration. There was significant corrosion on the existing secondary bus duct runs and oil sample analyses for both transformers were indicating increased levels in dissolved gases over the past ten (10) years, a sign that the transformers' internal insulation is aging.

It was determined that both existing transformers and associated secondary connections were approaching end of life conditions and should be replaced. Marcelino Moniz, Director of Facility Operations and Patient Access at Southlake, notes, "The continued reliability of our main electrical substation is critical in ensuring our hospital remains fully operational."

A number of important criteria factored into the design and planning for the replacement project. Besides the usual budgetary constraints associated with a project of this nature, the ongoing healthcare operations of the facility made any type of prolonged power outage impossible. The existing power distribution system topology allows for either transformer to feed downstream loads via a double-ended, secondary selective type distribution, and a careful review of the hospital's monthly electrical demand load profile indicated a six month window where the aggregate load is less than the rating of one (1) transformer. This meant that schedule would be a driving factor in the project and the manufacturing lead time of the replacement transformers would have to be taken into account, such that the site preparatory work and the phased installation would occur during the six month window, while reduced electrical demand load allowed for one (1) transformer to be removed from service.

The incorporation of sustainable design elements into the project was another important factor. Marcelino Moniz explains, "Southlake Regional Health Centre is committed to promoting sustainable development and we task our design professionals with including sustainable elements in our projects." LEED (Leadership in Energy and Environmental Design) design criteria for building electrical systems typically focuses on lighting and measurement and verification systems for energy consumption, and does not offer guidance for a project of this nature. By keeping up to date on industry trends and product options, good design practice offered several options that would fulfill the hospital`s sustainable goals. The new transformers were specified to meet CSA (Canadian Standards Association) standards for energy efficiency, which required the replacement transformers to have a guaranteed 99.25% efficiency at full load. A higher level of efficiency means there will be reduced energy losses over the service life of the new transformers and there will be a reduction in energy consumption. Another innovative feature in the design included filling the replacement transformers with an environmentally friendly insulating medium, FR3 Envirotemp®, derived from renewable vegetable oils, in lieu of using mineral oil which was used in the existing transformers. In the unlikely event of a future oil spill, the insulating medium is biodegradable to 99% within 21 days. The insulation also offers a number of improved performance characteristics, including: a higher fire point than mineral oil, properties that promote asset and insulation life extension and a significantly reduced carbon footprint.[1]

A fire-rated "blast wall" was installed in between the transformers, to help mitigate the risk of a failure in one transformer affecting the surviving transformer. Both transformers and supports for the secondary cable bus were bolted to reinforced concrete bases.



The replacement transformer is craned into position on the new reinforced concete base. The primary throat connection is installed above the transformer and 44kV bused connections are extended to the primary bushings. The secondary cable bus connection box is being readied for instillation.

photos courtesy of HH Angus

"Finding sustainable design elements for a project of this nature is not always as straightforward as applying prescribed requirements in a referenced standard. Staying up to date on the latest product developments and good design practice, are important in being able to identify innovative solutions to meet a client's requirements."

The design parameters, sustainable requirements and phasing/scheduling constraints were consolidated into a detailed set of drawings and specifications and the project was tendered to pre-qualified electrical contractors. This process ensured that a prescribed level of quality would be provided and project constraints would be adhered to, while minimizing costs through the competitive bidding process. The project was subsequently awarded to the successful electrical contractor and a detailed construction schedule was established. The generalized sequence of construction entailed: manufacturing the replacement equipment; the de-commissioning and removal of one (1) existing transformer and associated connections; preparing the site for the replacement transformer; physical installation of a new transformer; inspection, commissioning and energization of the newly installed transformer; and repeating the process for the second replacement transformer. To mitigate risk to the hospital, the duration where the entire facility's load was supported by the existing transformer was minimized. Construction proceeded on this basis and the electrical load was transferred to one (1) transformer while its counterpart was decommissioned and taken out of service. During its removal, a more thorough examination of the disconnected secondary bus duct reinforced the extent of the corrosion and the need for infrastructure replacement.

A mobile crane was erected to facilitate the removal of the existing transformer from site. Given the phased nature of the project, a number of mobile crane set-ups and lifts were required for removing and installing equipment.

Manufacturing of the replacement transformers was on the critical path for the majority of the project's schedule. With an 18 week lead time, both transformers had to be manufactured and tested to ensure their delivery coincided with other construction activities, and the downtime associated with one (1) existing transformer being removed from service was minimized. To ensure that quality assurance was not compromised with an expedited manufacturing schedule, a number of checks and tests were performed throughout the manufacturing process. The manufacturer was tasked with submitting a detailed set of shop drawings for the Engineer's review and approval, prior to commencing manufacturing. During the course of the manufacturing process, a number of factory witness tests were performed at various stages to ensure the transformers conformed to the specified design requirements. A pre-tank inspection was performed prior to the core and coil assembly installation and the filling of the insulating medium (FR3 Envirotemp®).

After in-house factory witness tests were completed, the transformers were shipped to a testing laboratory to undergo Basic Impulse Level (BIL) testing, designed to verify the transformers' insulation systems ability to withstand an overvoltage; typically associated with lightning strikes and power surges. The rigorous factory witness testing process ensured the transformers met all specified parameters and that any deficiencies were corrected, prior to the units arriving on site.

The delivery of the transformers was determined in advance of their arrival and the contractor worked on preparing the site to receive the new transformers. Site preparations included: the excavation and removal of the existing transformer base; installing a new cast in place, reinforced concrete base; and modifying the 600/347V switchboard for the new secondary connections. The mobile crane was set up and the first of replacement transformers was lifted into place. Following the installation of the transformer, the replacement primary throat connection was installed and the 44,000V bus connections were extended to the transformer's high voltage bushings.

A secondary cable bus system was installed from the low voltage bushings to the main 600/347V distribution switchboard in the central plant. The installation was commissioned, inspected and tested, before the newly installed transformer was energized. The ability to successfully carry load was determined and entire campus load was subsequently swung over to the newly installed transformer. The installation process subsequently repeated itself for the second existing transformer.

The thorough design and scheduling process resulted in the successful installation of both replacement transformers with no major issues or outages to Southlake.

In addition to being a success from an infrastructure replacement perspective, a number of innovative features were incorporated in the new installation. To further enhance risk mitigation, a fire-rated "blast" wall was installed in between the replacement transformers in order to minimize the unlikely possibility of a failure in one transformer affecting the surviving transformer. The fire-rated "blast" wall is a certified system, with its own dedicated foundations, and is constructed primarily out of concrete and steel. Additionally, the 4000A bus duct runs from the secondary of each transformer were replaced with a cable bus solution. With no joints and insulation suitable for outdoor installation, the cable bus system provides a compact replacement solution utilizing the free air rating of multiple parallel runs of power cables. Maintenance will be further reduced by removing the need to inspect joints, which are typically associated with bus duct installations.

Southlake Regional Health Centre was very pleased with the project and its outcome. Critical power distribution infrastructure was replaced, without impacting healthcare operations, and a number of innovative improvements were incorporated into the design, which helped reduce the installation's overall environmental footprint. Marcelino Moniz comments, "The project phasing and well thought out implementation were essential to reducing risk to our patients and staff. The improvements included in the design were an excellent way of contributing to Southlake's commitment to sustainability." The new energy efficient transformers will reduce losses and unnecessary energy consumption over their lifespan, further decreasing the installation's carbon footprint. The biodegradable insulating medium offers a number of improved performance characteristics and reduces risk in the unlikely event of an oil leak. Finding sustainable design elements for a project of this nature is not always as straightforward as applying prescribed requirements in a referenced standard. Staying up to date on the latest product developments and good design practice, are important in being able to identify innovative solutions to meet a client's requirements.

Critical facilities can follow a similar approach when faced with aging electrical infrastructure, the need for planned equipment replacement and sustainable development. Given the significant lead times with manufacturing high voltage equipment, replacement projects are necessary to ensure a reliable power distribution system is maintained and outages, due to equipment failure, are avoided. The first step towards undertaking a project of this nature, is performing a site survey and reviewing the condition of existing equipment, as well as existing service records and preventative maintenance practices. Once a case for equipment replacement is established, it is necessary to work with the end user to review the facility's operational constraints and possibilities for additional improvement. Presenting these findings in a report that identifies the current condition of infrastructure, available options for replacement and budgetary requirements will allow management to allocate funding to undertake the project. As evidenced by the successful outcome at Southlake Regional Health Centre, critical facilities can take a proactive approach to improving reliability system reliability through planned equipment replacement and capitalize on infrastructure renewal opportunities by utilizing sustainable design practices. SBD

Reference

[1] For further information, please refer to (*www.cargill.com/products/industrialdielectric-ester-fluids/envirotemp-fr3/index.jsp*).

Philip Chow, P.Eng., P.E., LEED® AP is an electrical engineer and project manager at **H.H. Angus & Associates Ltd. Consulting Engineers.**