Emergency Generators

Undertaking Critical Power Upgrades without compromising backup power.

Philip Chow, P.Eng., P.E.
Michael McRitchie, CFM, CCHFM, CHPA

36th Annual Conference of the Canadian Healthcare Engineering Society – Track 4A
September 12, 2016
Learning Objectives

✓ Describe how a complicated electrical infrastructure renewal project can be undertaken.
✓ Identify planning opportunities that promote operational savings.
✓ Discuss risk mitigation techniques to ensure critical operations are not impacted.
✓ Structure a project to meet funding requirements.
✓ Highlight *Critical Success Factors* and lessons learned.
Sunnybrook’s Bayview (Main) Campus

Central Utility Plant
Sunnybrook’s Bayview (Main) Campus

- Full-service 1200 patient bed hospital located in Toronto.
- Affiliated with the University of Toronto.
- Partnered with Veterans Affairs Canada and home to 500 veterans.
- Largest regional trauma centre in Canada.
- Largest maternity hospital in Canada.
- Aggregate campus area of approximately 3 million square feet.
- Buildings of varying vintages, with the oldest areas dating back to the 1940s.
Existing Central Utility Plant
Existing Central Utility Plant

• The Central Utility Plant provides a number of critical services to the campus: heating, cooling, utility power and emergency power.
• Existing Generator Plant consisted of two (2) separate power generation and distribution systems: 4160V for campus substations and 600V for central plant systems.
• Seven diesel generators of varying vintages, with the oldest three dating back to the 1970s, provided 4.3MW at 4160V and 1MW at 600V.
• Existing generator sets were approaching end of life with frequent need for replacement parts and major overhauls.
Existing Diesel Generator Plant
Existing Emergency Power Distribution

• The emergency power system utilized a traditional dead bus type control system. First generator online serves highest priority loads.
• PLC load management system controlled approximately 20 electrical substations around the campus and would add/shed load based on available generating capacity.
• Existing switchgear and paralleling controls were of varying vintages, with the oldest dating back to 1972.
• Issues with serviceability due to mix and match.
• Equipment was approaching end of life conditions with limited replacement parts.
• Sunnybrook recognized the risk to reliable operation and patient safety and retained HHA to perform an infrastructure assessment.
Existing Emergency Power Distribution
Initial Concepts for an Upgrade

• In-situ replacement of existing generator sets, with a marginal increase in size for new loads and redundancy.
• Utilize roll-in replacement type circuit breakers for medium voltage switchgear and upgrade controls within existing equipment.
• A third party review provided additional options for consideration.
• The team determined that partial renewal was the **WRONG** approach and would offer a BAND-AID solution!
Project Goals - The Right Approach

• Complete replacement of all generators and emergency power distribution equipment that have reached end of life conditions.
• Establish project goals that allow Sunnybrook to move forward:

  ✓ Increase capacity for emergency power load growth.
  ✓ Standardize on replacement equipment.
  ✓ Improve system operability.
  ✓ Conform with current codes and standards.
  ✓ Incorporate options for reducing annual operating costs.
Project Constraints

- Build within the footprint of the existing central utility plant – new service space was not an option.
- Maintain a reliable emergency power supply for Sunnybrook’s critical loads.
- Allow for a flexible implementation that would be adaptive to funding constraints.
Initial Planning – Project Phasing

• Site investigation confirmed that a complete plant upgrade could be accomplished in two phases.
• Under the first phase, a portion of the existing emergency power system would be removed to facilitate upgrades to half of the existing building, required for the installation of new larger generator sets.
• Once the first phase was completed, the second phase of the project would see the remaining building upgrades be completed for the additional larger generator sets.
Temporary Provisions

• To support critical hospital loads during construction, a number of temporary provisions would be required.
  ✓ A temporary generator to support diminished generating capacity
  ✓ Temporary controls and automatic transfer capability to provide emergency power from the temporary generator.
  ✓ A temporary fuel oil supply to allow for existing equipment to remain operational, while main fuel system was upgraded.
  ✓ Temporary settings for the existing load management system.
  ✓ Temporary load transfers at various points in the campus distribution system to maintain capacity restrictions.
  ✓ Build in redundancy in temporary installations.
Equipment Pre-Selection RFP

- Sunnybrook’s end users wanted direct input into equipment selection.
- Engineered drawings and specifications were prepared for the new emergency power generators, switchgear and control systems as part of an RFP package for potential suppliers.
  - *Pre-selection of the equipment through an RFP process, with price weighted at less than 50%, removed the equipment selection from the contractor’s scope of work and led to the selection of a high quality equipment package.*
- Sunnybrook led committee established evaluation criteria for the RFP.
Equipment Design Requirements

- 4x1.5MW diesel generators were initially considered, however there was desire to maximize campus generating capacity.
- Pricing options for 4x2MW, 4x 2.25MW and 4x 2.5MW diesel generators.
- Increase power plant generating capacity with 1x750kW diesel generator set.
- New Automatic Transfer & Distribution Switchgear, Allen Bradley IP-based load management system and controls.
- Itemized pricing for splitting equipment between two phases to give flexibility for funding constraints.
Equipment Supplier Award

- Given the interrelated functions of the new generators, controls and switchgear, the generator supplier would be responsible for the entire equipment package.
- The prime supplier would coordinate the supply and commissioning of major equipment items.
- The RFP was awarded to Toromont CAT and production of equipment shop drawings commenced after award.
Design & Construction – Prime Consultant

• Based on information and pricing received from the equipment pre-tender, the installation was designed for 4x2MW diesel generator sets.
• Fuel oil system upgrades, structural upgrades and a building expansion for an increased air intake and exhaust plenum were required.
• H.H. Angus & Associates was the prime consultant for the project and the various disciplines were coordinated around electrical phasing requirements.
• Engineered drawings and specifications were produced for each discipline.
Prime Contractor: *Electrical or General?*

- Given the significant electrical work, the project was tendered to pre-qualified electrical contractors and the successful contractor would assume the role of the prime contractor.
- The pre-selected equipment package was assigned directly to the contractor, such that equipment production, deliveries and testing could be coordinated directly with site activities.
- Shop drawings for equipment were reviewed prior to tender, to save time on project schedule.
- The bids were submitted and pricing & schedule were analyzed.
- As the review was ongoing, a massive weather event impacted the Greater Toronto Area!
The December 2013 Ice Storm
Impact of the 2013 Ice Storm

• Freezing rain downed overhead power lines all over Ontario.
• At the height of the storm over 400,000 customers were left without utility power in the GTA.
• Sunnybrook lost power on both incoming 27.6kV utility feeds for over 39-hours.
• After several hours of operation, Sunnybrook’s existing generator plant experienced an unexpected outage, with 4 out of 5 campus generators shutting down.
• Shutdown generators were restored after several hours, however the impact was felt throughout the hospital.
• Contributing factors included: no bypass valves around day tank solenoid valves, lack of automated alarms and a single power source for day tank controls.
Award of Contract

• The storm’s aftermath further reinforced the need for a reliable emergency power system.
• The contract was awarded to Ontario Electrical Construction Company Ltd.
• The project schedule was refined, along with the contract cost breakdown and estimated cash flow forecasts.
• A spend profile for the project was established to meet funding deadlines and specific project milestones.
• Progress against multiple project milestones would be tracked separately and payments would be made accordingly.
Temporary Provisions – On Site

• The contractor mobilized on site and production of emergency power equipment commenced.
• The contractor started with the enabling works for the project.
• A temporary fuel oil supply line was connected from the boiler heating oil supply system to the remaining generator plant.
• A rental generator was installed and connected to 5kV Temporary Switchgear, complete with automatic transfer controls.
• Two (2) 5kV campus distribution circuits were spliced to the temporary system and modifications to the existing LMS were made.
• Temporary 600V generation was provided for the central plant.
Temporary Equipment & Contactor’s Area

Contractor’s Area

Temp Fuel

2MW Temp Generator

5kV Temp Switchgear
Temporary 5kV Distribution Circuits

Temporary 5kV Distribution Circuits Installed – Back-up power by temp generator.

Temporary HV Cable Splices
Other Temporary Provisions

- Relocation of Remote Radiators
- Temporary Fuel Oil Supply and Day Tank Relocation
- Temporary Power for 600V CUP Circuits
- Revisions to Existing Load Management System Controls & HMI
Phase 1 Construction – General Trades Work

- Plant equipment was removed, interior and floor slab were demolished.
- New structural steel for air intake/exhaust plenums and combustion exhaust systems.
Phase 1 Construction – General Trades Work

- New reinforced monolithic concrete bases for larger generators.
- New floor slabs were poured and diesel emissions reduction system modules are installed.
New Equipment - Integrated Witness Testing

• Diesel generator sets, paralleling controls and 5kV switchgear were shipped to an off-site testing facility and assembled.
• The new emergency power system underwent rigorous operational testing, complete with failure modes, designed to simulate how the system could be expected to operate following installation.
New Equipment - Integrated Witness Testing

- Portable, reactive power, load banks were used to simulate hospital load and a portable diesel generator simulated utility power.
- Parallel operation between project generators and a simulated utility was verified, and operational data including switching transients were recorded.
After the equipment successfully passed the integrated testing, it was shipped to site and set in place by industrial movers.

Each 2MW generator weighed approximately 45,000 lbs.
Phase 1 Construction – Near Completion

- M&E infrastructure for Phase 1 was installed in the interior of the new plant, while exterior work was completed.
Phase 1 – Complete

- The first half of the new generating plant was *commissioned with extensive failure scenarios* and hospital loads were transferred from the temporary switchgear to the permanent switchgear.
- Hoarding separated the new plant from the remainder of the existing plant and access to the new Phase 1 plant was restricted.
Phase 2 – The Process Repeated

- The remaining distribution circuits were transferred to the temporary switchgear, to facilitate Phase 2 construction of the new plant.
- The same process was repeated: demolition, general trades work, integrated factory witness testing for Phase 2 equipment and installation. Partitions were removed, when the Phase 2 plant was near completion.
Sunnybrook’s New Generator Plant

- With the partitions removed, Phase 1 infrastructure was connected to equipment installed under Phase 2 of the project.
- Phase 2 systems were commissioned, tested and the remaining hospital loads were transferred from the temporary switchgear to the new plant.
Sunnybrook’s New Generator Plant

• Complete dynamic system testing was performed during off peak hours.
• System redundancies, emergency modes of operations, anticipated responses due to simulated component failures and load management control of the 20 downstream electrical substations were tested.
• Thorough testing corrected several minor software bugs.
Project Successes – System Improvements

- Increased aggregate generating capacity by a factor of 1.76.
- 8MW of 5kV generating capacity is representative of approximately 50% of peak electrical demand load (15MW).
- Improved response time from having 0.8MW online within 10 seconds to 4MW online – CSA Z32 requirement for vital loads.
- Redundant sets of transfer breakers – bypass system for each ATS.
- Intelligent IP based load management system that makes decisions on actual system load.
Project Successes – System Improvements

• Day tanks were grouped in a common area with a protective curb.
• Fuel oil system functionality was improved with branch line shut-offs, in lieu of main shut-off, and added bypass valves.
• Improved fuel oil controls with user friendly HMI screens for each day tank.
• Fuel lines in slab service trenches covered with steel checkerplate.
• All main emergency power system alarms are recorded with timestamps.
• Staff receive email and SMS text notification from LMS alarm system.
Project Successes – Risk Management

• *Detailed work plans were created and scrutinized to ensure minimal risk.*
  
• Testing and cutovers were completed during off-peak hours.

• Sunnybrook’s internal review process between plant operations and various user groups, for all proposed work.

• Safety was a high priority - circuits were isolated around the campus.

• Project schedule was managed and discussed at every project meeting and related to the spend profile. The project was completed on schedule (approximately 90 weeks).
Innovative Design Features - DERS

- Diesel Emissions Reduction System (DERS) modules were installed on each new generator set.
- DERS modules improve generator emissions from US EPA Tier 2 levels to US EPA Tier 4 levels.
- The system was installed complete with urea storage tanks and dosing infrastructure for extended run-time.
- Modules have built-in sound attenuation – no added muffler req’d.
- 95% Reduction in nitrous oxide NOx emissions.
Innovative Design Features – Controls

- Closed-transition transfer logic implemented on site, allowing for momentary paralleling of utility power with generator power.
- SCADA connection for Toronto Hydro.
- Reduces momentary interruptions to critical hospital loads, during weekly testing.
- Variable load sharing allows user defined percentage split for generator pairs. Useful to fully load a particular generator for annual full-load testing requirements.
Operational Savings – Improved Operability

• IESO levies Global Adjustment Costs on customers with a peak demand load 5MW or greater, as an incentive to reduce load during provincial peaks.

• With a 15MW peak demand, Sunnybrook is subject to this surcharge.

• By reducing the campus peak demand during 5 peak days, significant cost savings can be achieved.

• New generator controls and DERS modules allow Sunnybrook to seamlessly transfer campus load to generator power and can help reduce these costs.

Image from: www.ieso.ca
Independent Electricity System Operator
Operational Savings – New Equipment

- Improved equipment reliability will reduce unexpected outages.
- Costly, unexpected repairs were associated with end of life equipment.
- Standardization offers improved serviceability.
- Common maintenance materials.
- Training and operating procedures are simplified with consistent equipment.
- Email and SMS alarm notifications provide improved response times.
- Detailed system alarm lists reduce troubleshooting time.
Critical Success Factors & Lessons Learned

- Detailed design work and exploring multiple options for the project.
- Equipment pre-selection gives the user the ability to choose options.
- Temporary infrastructure can be unreliable – build in redundancy.
- Off-site testing will help correct operational issues in advance.
- Extensive commissioning with equipment failure scenarios.
- Detailed work plans were completed with risk reviews.
- The entire team was engaged and dealt with every risk to patient safety that materialized throughout the project.
- Standardization is important for operations and reliability.
- Issues experienced during the 2013 Ice Storm were resolved with innovative design features.
Concluding Thoughts

✓ Complex infrastructure replacement projects can be achieved.
✓ What’s best for your facility? Partial upgrades or complete renewal?
✓ Plan for the future and improve on operability, reliability, capacity and redundancy.
✓ Explore multiple options to help users make informed decisions.
✓ Push your engineering consultants into providing varied concepts.
✓ Temporary installations and “throw away” money are necessary to achieve the end goal.
✓ These concepts can be applied to any type of project.
Questions?
Thank you.