London Underground Gets a Power System Overhaul

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The London Underground (LU) comprises 408 route kilometers and serves over 900 million passenger journeys each year. Following the November 2002 decommissioning of the power station that previously supplied power to the Underground, all power is now supplied from the UK electricity grid. The annual demand for power has now exceeded 1TWh.

The control of the power supply system is carried out on a continuous basis by control room engineers and operators responsible for the safe and reliable supply of power for traction, signaling, lighting, station services, tunnel ventilation, and escalators. The DC supply to the various traction sections is switched off following the last train at night and switched on before the first train in the morning. This allows work to be carried out safely on the railway while trains are not running, and typically results in over 500 switching operations per day. These factors make the power supply control system and the people who operate it critical to the railway.

From the Editor

This issue takes a wider view of Network Manager’s applications. Our main feature describes the London Underground’s efforts to restructure and update its power supply infrastructure, and we also hear from Belgium’s grid operator Elia as they attempt to build a better simulation engine.

Also in this issue, we provide a brief look at some of the many enhancements that are being made to Network Manager for the next release. As always, feel free to pass the newsletter on to your colleagues, or contact me to add them to the distribution list.
Power Private Finance Initiative
On August 16, 1998, the Power Private Finance Initiative (PFI) contract commenced. 323 London Underground employees were transferred to SEEBOARD Powerlink (SPL), a company set up for the specific purpose of operation, maintenance and renewal of the power supply system. This new company has a thirty-year, $1.8 billion contract with London Underground (LU) and was jointly established by SEEBOARD plc (now part of EDF Energy), ABB Ltd., and BICC plc. This consortium was formed to bid for the PFI contract, and prevailed in March 1997. Since then it has been working closely with LU to allow a seamless transfer of staff, functions, assets, risk and responsibility. The contract is performance-based so that SPL is required to provide electricity to reliability, quality and safety standards set and monitored by an LU contract team.

Boundaries of Responsibility
In order to establish a clear interface between the two companies, boundaries were defined in the contract with regard to operation, control or switching, and maintenance areas. In terms of the power supply system, the substation plant became the operation and maintenance responsibility of SPL, although some supplies are still controlled by LU. The control of final connections to the railway, including DC supplies direct to track sections and direct LVAC supplies to stations, remains the responsibility of the individual Line Control Centres. This is defined as “Interface switching”. The remaining distribution circuits that interconnect traction substations at various voltages are controlled by SPL. These include 22kV, 11kV, and LVAC circuits, as well as the compressed air and the 125 Hz and 331/3 Hz signal networks.

Changes in Operational Philosophy
Prior to the Power PFI contract, two electrical control rooms had been established. The Shift Supply Engineer’s office had overall responsibility for the continuous operation of the power supply system, and was directly switching the primary (22kV) distribution via the 22kV SCADA system. The rest of the power supply system was controlled from the second (and larger) control room, which contained the five SPARCS desks and the Central Line SCADA workstation. Operators at these desks took operational instructions from the Shift Supply Engineer and from the Line Controllers for each Underground line.

The operational philosophy under the PFI contract allowed for an SPL control room with Shift Supply Engineers responsible for the control of the whole power supply system, with the exception of “Interface switching” (i.e., the final connection to the railway). The primary function of the Shift Supply Engineer has been changed to the provision of power at agreed delivery points, within parameters set in the contract. The LU Control Room is responsible for the control of “Interface switching” at the delivery points in close co-operation with Line Controllers at each Line Control Centre.

Until new SCADA systems are in place to allow LU and SPL to directly control their respective responsibilities, Technical Interface Procedures have been established under which switching of plant has remained as it was and responsibility for control has been divided along the contractual boundaries. Operators had to familiarize themselves with the way in which the contract governs how they are to work, and their new responsibilities. A change in culture was required on both sides of the contractual divide. The operators that were transferred from LU to SPL took on additional responsibilities but were divorced from the business of running trains, while the operators remaining with LU become closer to the core business of running trains.
Initial Works Project
As part of the initial investment into the power supply system over the first five years of the PFI contract, the main LU power station was decommissioned and power to the railway is now exclusively supplied from the UK electricity grid. In the event of power station failure, a backup power supply to critical loads at each sub-surface station (e.g., lighting, public address, and communication equipment) is provided by a local electricity supply. This is for the safety of passengers and is also a legal requirement under the London Transport Act of 1971. In order to achieve this back-up power supply following the decommissioning of the main power station, off-line battery inverter systems were installed to supply critical loads at each sub-surface station.

The second LU power station, initially used for peak lopping, has been refurbished and is now an emergency power station. UPS and off-line battery inverter systems maintain essential services for a minimum 15-minute duration (designed with installed capacity for 1 hour) immediately following an electricity grid failure. Within this time, the power distribution can be reconfigured and a generating plant started to feed these essential services for a longer period of time. Tests of this failure scenario are carried out regularly.

PFI SCADA System
In addition to the extensive works required for the other power system upgrades, the LU/SPL team also installed a new integrated high performance SCADA system using power control technology from ABB—Network Manager. The chart at right summarizes the changes being made.

<table>
<thead>
<tr>
<th>Control System</th>
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<tbody>
<tr>
<td>Central</td>
<td>SPARCS system has been replaced as part of the Central Line Modernisation</td>
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<tr>
<td>Northern</td>
<td>SPARCS system replaced as part of Northern Line Modernisation</td>
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<tr>
<td>Eastern</td>
<td>Four SPARCS systems and 22kV system are being replaced by PFI SCADA system.</td>
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<tr>
<td>Western</td>
<td>Metropolis</td>
</tr>
<tr>
<td>Metropolitan</td>
<td>22kV Distribution</td>
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<tr>
<td>Jubilee Line</td>
<td>New SCADA system installed as part of the Jubilee Line Extension Project.</td>
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</table>

The principles and criteria applied in the selection and configuration of the SCADA system included the following:

- Safety and security of control consistent with the Underground railway application
- Flexibility to allow for future expansion and/or change of organisational strategy
- Specified requirements for performance, availability, reliability and maintainability
- Provision of system-wide facilities such as power system management software, easier plant fault diagnosis, and partially automated power system restoration
- User requirements of both LU and SPL
- Requirement for proven technology, and best industry practice
- Experience and knowledge available and studies carried out on existing systems and locations
System Configuration
The configuration of the Power PFI SCADA solution comprises a main control centre and an emergency control centre. A single network-based SCADA computer system was established, with dual application servers at each of the two control centres, interconnected by a high-speed communications network. The technology used includes Digital AlphaServer DS20 64-bit computer systems, 100Mbit Ethernet and FDDI communications networks, and Digital VNswitch 900 network switching products.

Operator workstations in all control rooms are connected to the high-speed communications network. Each workstation is able to connect to any of the four application servers depending on the mode of operation of the SCADA system. Various operational modes were defined to address unavailability of equipment, communications, workstation, control room, or control center.

As the RTUs remain largely in good condition with a reasonable remaining life, these will be replaced according to a program based on age, condition and fault history, or in line with substation plant replacement. Consequently, data concentrators were installed at the existing emergency control rooms. It is at these locations that the copper communication lines from each RTU converge, and each dedicated line can be picked up. Protocol conversion software was also developed and incorporated into the data concentrator systems. Using leased fiber-optic communications lines, these data concentrators are networked with the main and emergency control centers.

Areas of Responsibility
Because all of the power supply system is potentially accessible to all operators, some division of responsibility had to be incorporated into the SCADA system. Network Manager was configured to provide a clear view of the system over which a given operator has responsibility. All alarms and events are only relevant to the area of responsibility, and are routed exclusively to the operator who is required or able to act on them. While there is significant advantage in being able to see the larger picture, particularly in the event of a system-wide disturbance, the SCADA system prevents the interference of one operator in an area where another is responsible. This is particularly important because operators on the same SCADA system belong to different companies.

Human Machine Interface (HMI)
The starting point for HMI development was inevitably the previous control systems, of which SPARCS is the benchmark. It was important, however, to consider new technology and use this to implement the best of the previous designs. For example, technologies for large screen displays have been introduced to replace the mosaic tile indication mimics on each SPARCS desktop and in the Shift Supply Engineer’s office. The design team also visited other control rooms where similar SCADA systems are used.

VDU-based displays are able to make use of pixel-based graphics, pan and zoom functions and levels of de-clutter. This is considerably more powerful than the text page displays implemented on SPARCS. However, given that the HMI’s purpose is to present the operator with timely information, and facilitate efficient control of the power supply system, it would not be desirable if it was unduly complicated to navigate. Alarm prioritization and filtering provides operators a clear presentation of alarms and their relative importance.
The following six alarm filter categories have been implemented:

- Circuit breaker status, track alive status, and alarms for protection operated and loss of control
- Tunnel Telephone override, DC protection override, general protection override
- Warnings related to transformer tap changers, general protection, compressed air, etc.
- DC protection status and general protection status
- On Local
- Fire Protection

Each alarm category is represented with a button at the system window which enables the operators to bring up the corresponding alarm sub-list and navigate to the pictures representing the equipment using the locate function.

Advanced functions such as state estimation, load calibration, load flow calculation, contingency analysis, automated sequencing of controls, calculations and derivation of telemetered data, dynamic network colouring, and short circuit analysis have also been implemented. Partially automated control sequences will be used for rapid restoration following power system outages, and for reconfiguration of the power system to allow emergency back-up generation to be started.

**Management of the SCADA System**

Maintenance and administration have also been affected by the implementation of the new SCADA system. The increasing reliability of electronic equipment, the self-diagnosis of electronic systems in the event of a fault, and the current philosophy of “condition-based maintenance” resulted in greater intervals between routine maintenance visits. However, with the increasing complexity of communication networks and computer systems, the functions of the “system administrator” become more onerous. The Power PFI contract specifies levels for availability and maintainability, but careful allocation of resources and competencies must also ensure that these levels are achieved.

**Project Philosophy and Implementation**

Scientific research into successful project management came to the conclusion that it is behavioural and organisational factors rather than technical issues that are likely to have the most impact on successfully implementing projects. Consequently, attention has been given to ensuring the involvement and commitment at the earliest possible stage of the end users and clients from both companies.

A joint implementation team was set up comprising an LU Operations representative, an LU Client Engineer representative, an SPL Shift Supply Engineer, and an SPL SCADA Engineer along with representation from the supplier, developers and system implementers. This team has formulated the Functional Design Specification, and been responsible for the development of functionality, interface with existing equipment, building of new control room facilities and interconnecting Wide Area Network (WAN) as well as the installation, testing and commissioning of the new Power PFI SCADA System.
New SCADA System Reduces Risk of Nantucket Becoming Electrical Island
Bill Tsolias, National Grid USA

One of the worst things that can happen in a power system is to have an “electrical island,” where a portion of a power system is separated from the main part of the system. Now imagine that happening on a real island. This is the problem that can face National Grid USA’s Nantucket Island service territory.

Yet, by leveraging technology from the company’s Westboro Energy Management System (EMS), the EMS IT staff delivered a cost-effective solution to Nantucket Island that will increase operability and reliability for the entire island.

A solution became necessary due to concerns related to the Nantucket Island SCADA system and a decision was made to look at options for a new SCADA system. A team made up of groups from the New England Distribution Operations department and EMS IT provided requirements to vendors and reviewed proposals before settling on a solution with ABB. Work to implement the solution started in April 2004.

The ABB solution was a scaled down version of the current EMS in Westboro, allowing NGUSA to leverage the Westboro EMS. Making the ABB solution even more attractive was its ABB Start System, which allows individual modules of the complete system to be removed during initial configuration. For the Nantucket Island system, only the basic SCADA modules were needed since the database and displays were already available via the Westboro EMS, and only needed to be imported to the Nantucket Island SCADA system.
Delivered to Nantucket Island in June 2004 and going online in July, the new Nantucket Island SCADA system eliminates the need of three key remote terminal units (RTUs) to communicate with each other. Instead, each of the three RTUs—located at Lothrop Avenue, Harwich, MA, Candle Street, downtown Nantucket Island and Bunker Road, on Nantucket Island—communicate with the Westboro EMS and the Nantucket Island SCADA system independently. With this independence, both the Westboro EMS and Nantucket Island SCADA system have the ability to control and monitor the Nantucket Island electric system.

“This really lessens the chance of an interruption of service on Nantucket Island and allows the Company to control the power to the Island with confidence,” says Brian Finn, Principal IT Analyst.

“With the decision made to reconfigure the Nantucket Island RTU, a decision also needed to be made on the Island’s network and communication medium,” adds George Kalavantis, Principal IT Engineer. “Instead of numerous conventional digital data service (DDS) circuits between each of the sites, we decided to use T1 circuits in conjunction with a product from Verilink.”
The Verilink product interconnects the internet protocol (IP) traffic between the sites and provides the serial communication requirements. The serial traffic is encapsulated in IP. Built in serial ports are used at each end. This means that no changes are needed to the existing RTU hardware. The Verilink products also allowed the prioritization of the serial SCADA data, assuring that the RTU data would have a higher priority.

There are many benefits with the overall ABB implementation. The implemented system was derived from a system with high reliability (99.998% uptime). The workstations/servers are hardened UNIX based boxes. The main system is backed up by an uninterruptible power supply (UPS) and an emergency generator ensuring that any power outage to Nantucket Island will not adversely affect the performance of the Nantucket Island SCADA system.

The maintenance complexities of the previous Nantucket Island system also have been eliminated. The hardware is now covered by the same maintenance agreement the covers the existing HP/Compaq hardware for the Westboro EMS. The software will be maintained by ABB, with the EMS currently in its second year of a four-year maintenance agreement. All relevant software patches and upgrades that will be implanted on the Westboro EMS will be incorporated into the Nantucket Island SCADA system. However, the software patches will be fully tested before being loaded onto the Nantucket Island SCADA system.

Maintenance also is reduced because of the in-house expertise of National Grid USA’s EMS IT staff, which maintains the Westboro EMS. This expertise along with the support of the ABB staff will ensure the maintainability of the Nantucket Island SCADA system for many years to come. The ABB implementation also provides a highly scalable system.

**Tri-State G&T Moves Up to Network Manager**

Tri-State Generation and Transmission Association, a cooperative owned by 44 member rural electric systems, is migrating from their current ABB SCADA system to Network Manager in order to take advantage of the newer system’s features and functionality. The contract, signed in August, calls for a dispatcher training simulator to be deployed by the end of 2004. The main system will utilize HP’s new Itanium servers, which will become available early next year, and the entire system is scheduled to be online by 2006. Tri-State manages more than 5,000 miles of transmission lines, including one of seven DC interties between the Eastern and Western interconnects in the U.S.

Additional benefits from the new SCADA system also should be recognized as NGUSA installs a second cable to Nantucket Island to go along with the existing single 46KV undersea cable. Projected to be in service by the end of 2005, the integration of the new cable into the overall distribution system will be much easier with the combination of the Westboro EMS and Nantucket Island SCADA system.
Belgian transmission system operator Elia operates a transmission system that includes 8,000 km of overhead lines, underground cables ranging from 30 to 380 kV, 800 substations and 140 generators. The company values simulators for dispatcher training and used to rent time on an existing generic simulator for that purpose. Yet Elia was confronted with several shortcomings, such as differences in controls and market characteristics between the simulator and the actual Belgian network. Consequently, Elia decided to update its training program specifications towards more realistic training scenarios.

After examining the market, part of Elia’s training program was awarded to Tractebel. The company presented extensive experience in network simulation and simulation tools. In answer to Elia’s needs the Tractebel team set out from the beginning to create an entirely new type of simulator, one that would overcome some of the limitations of traditional models.

Most transmission system models are derived from an attempt to model specific phenomena. As a result, however, each specific phenomenon produces its own model. This approach tends to encourage solutions that address events separately, which may not cope with some real-world situations where events occur simultaneously. In a similar way, traditional models also tend to focus on static or slow-evolving scenarios that humans can perceive while neglecting the fast-occurring events that may also play a role.

The upshot of the traditional approach to network modeling is that the resulting model may not represent the dynamic behavior with transients of the transmission network, nor likely work processes, as accurately as it should. This is what Elia sought to overcome. The company also wanted to have a simulator that would adapt with the evolution of the actual network so that the tool would remain highly useful in the foreseeable future.

The “Generalized” Model
What Tractebel came up with is a unique simulation engine that is able to cope with all types of electrical phenomena (static, slow moving, fast moving), regardless of whether they occur sequentially or simultaneously. This more holistic approach yields a much more realistic representation of the network across a generalized variety of operating conditions.

The so-called “generalized” model can imitate an array of actions and events including:

- Operation of breakers, relays, and other equipment like voltage compensators
- Generation control actions
- Short circuits on busbars, lines, or transformers
- Generator loss of synchronization
- Black-start of the network
- Frequency or voltage collapses up to a blackout
- Inter-zonal oscillations and power swings
- Untimely relay tripping or breaker failures
The model is also compliant with parallel processing to improve performance, and mirrors the division of tasks in actual network control systems. Based on a dual processor server, for example, the model will use one processor for network and generation control, and the other for simulating relays, protection, and regulation processes.

In implementing the model, Tractebel, within the framework of an ongoing collaboration, turned to ABB to provide the operational environment for the simulation engine. The generalized model was then integrated into the Network Manager database, ELIA being a longtime user of ABB’s SCADA/EMS systems. Tractebel used a data extract from the Elia model of the Belgian network, and linked the Network Manager control tools to the simulator via the ELCOM protocol. The resulting FAST-DTS, working within the Network Manager environment, can be configured for multiple views to represent the geographic and functional divisions in how the grid is operated. It can provide vital information to the grid operator on critical power paths, thus delivering the means to avoid potential blackouts, and it can also be used for post-mortem analysis.

Elia is using FAST-DTS for training all its dispatchers, but the company sees other applications as well, such as development of emergency procedures and testing advanced control functions in a safe but realistic environment.

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*Elia’s FAST-DTS simulator in relation to the actual network.*
Events Calendar

<table>
<thead>
<tr>
<th>Date</th>
<th>Event</th>
<th>Location</th>
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<tbody>
<tr>
<td>Sept 21-22</td>
<td>Network Manager User Group Meeting</td>
<td>Gothenburg, Sweden</td>
</tr>
<tr>
<td>Oct 10-13</td>
<td>PSCExpo</td>
<td>New York, New York</td>
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Product Update
The latest release of Network Manager incorporates a vast array of enhancements and new features. The summary at right highlights only a few. For a detailed breakdown of the system's new capabilities, contact your ABB representative to request a copy of the Release Notes.

Coming in the Next Issue...
Our next issue of Network Manager News will be published in the fourth quarter. To submit articles, contact the editor at: bob.fesmire@us.abb.com.

Data Acquisition
- 13 New RTU protocols added; Data Concentrator Status Point Enhancement; Phase Imbalance Monitoring.

SCADA Platform
- Complete Implementation of CIM Toolkit; Optionally store value and quality in the same OSI PI tag; Utilities to create CSV files from Oracle and Network Manager tables.

HMI
- User interface of all SCADA applications redesigned to take advantage of the new features in WS500; PED 500 – PC based stand alone Display Building tool provides tools to convert displays built with DISGEN to the new PED format; Display file format dramatically changed to allow easy exchange of the display files.

SCADA Applications
- Supports up to 16 tag types, each mapped to one of the Network Manager tagging functions; Supports multiple map boards, each one having a different set of lamp definitions; Allows each console to be mapped to a particular time zone; Supports auto-acknowledge of application-generated alarms in addition to the SCADA alarms.

Communications
- Talarian based RTDB data exchange protocol has been added to exchange data with the OMS system.

Generation Control
- Support for multiple control areas; Improved handling of Jointly Owned Units and Combined Cycle plants; Handling of Fuel Mixes and pre-scheduling of fuel data; Identification of Wind Units; Enhanced support for generating unit startup/shutdown costs.

DTS
- Capability to model multi-boiler generating units has been added; Modeling of wind generation.

Integration
- Baseline tabular displays delivered in IDCS, the same configuration management tool as used for source code; RIS server changed to improve overall security of the system (e.g., removed login IDs with no password etc.)