DESIGN AND OPERATIONAL PHILOSOPHY FOR A METRO POWER NETWORK SCADA SYSTEM

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Introduction

The past decade has seen a dramatic change in the way British transportation companies are managed, operated and regulated. At an operational level this has led to the operators taking more responsibility for matters that have traditionally been outside their control.

This paper proposes a philosophy for a power network SCADA (Supervisory Control and Data Acquisition) system in a metro environment that fits in with the new organisational structures. It describes the development of the London Underground power system control and monitoring structure and philosophy, and discusses the development of the Central Line and New Northern Line SCADA.

Definitions & Abbreviations

The following definitions and abbreviations have been used in this paper:

ac	alternating current
CCTV	Closed Circuit Television
dc	direct current
HMI	Human Machine Interface
hv	high voltage
I/O	input/output
LAN	Local Area Network
LUL	London Underground Ltd
lv	low voltage
MIS	Management Information System
OSI	Open System Interconnection standard
REC	Regional Electricity Company
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SPARCS	Stored Program Automatic Remote Control System
SSE	Shift Supply Engineer
UPS	Uninterruptible Power Supply
VDU	Visual Display Unit

LUL Power System

The LUL Power System comprises a 22kV distribution ring network which feeds the lines via 11kV radial networks.

The power requirements for the 22kV ring network is supplied from two LUL generating stations or the National Grid. The 11kV radial networks are primarily used to supply sub-surface or underground sections of the railway. The generating stations are not operated in parallel with the National Grid. This enables local REC supplies to be used at the sub-surface stations to provide an alternative supply for 25% of the lighting load and other emergency systems.

There are three bulk supply points connected to the local REC which supply some of the surface sections of the railway at either 11kV or 22kV via radial networks.

Presently, plans exist to supply both the surface and sub-surface sections of the railway from the National Grid system. This will involve using 2 extra bulk supply points to feed the 22kV ring network. It is intended that the existing generation, in conjunction with battery UPS's at the stations, will be used to supply lighting loads and other essential equipment in the event of a major power supply failure.

History

Traditionally, within LUL, power has been kept as a separate operational entity from signalling and communications.

Originally each traction substation was manned 24 hours a day with control being carried out by the substation attendants.

In the 1930's direct wired control was introduced allowing a number of traction substations to be controlled from a local centre.

These direct wired controls were replaced by electromechanical systems using telephone exchange technology and were gradually replaced in the 1960's with semiconductor devices which mimicked the electromechanical operation.

In 1979 the computer based SPARCS was introduced and until the recent upgrade of the Central Line has been used as the main power control system.

Remote satellite control rooms can be used as emergency control rooms in the event of SPARCS failure or evacuation of the main power control centre.

SPARCS

There are six control systems (SPARCS) within LUL installed upto 17 years ago by Ferranti International.

Each are driven by dual Argus Computers and have Ferranti substation RTU's.

The present system performs satisfactorily the function for which it was designed for, although it is faced with reduced reliability due to its age. The system capability, however, cannot meet the requirements for line modernisation or devolution of control of items of plant within the same substation from separate control centres.

Additionally, the changeover of the substations from the existing to the new for an earlier project had proved to be very difficult, time consuming and costly due to the extent of the enabling works.

LUL Current Business Process and Future Developments

The individual Lines within LUL are operated as separate Business Units. These Business Units have responsibility for the rolling stock, stations, permanent way, communications and signalling equipment that comprise the assets of their Line. The Business Units are responsible for maintenance and operation of these assets.

The power assets are presently outwith the responsibility of the Lines. It is intended to make each Business Unit responsible for the cost of the energy used by its Line's stations and rolling stock. Also, due to the close relationship between operation of a Line, operation of its signalling system and the operation of the power feeds to that Line, LUL has a policy of devolving power system control to the Lines. The Lines will become responsible for the lv ac supplies to the stations and the dc traction power feeds to the track.

Careful consideration of the future is currently being undertaken, however, it is likely that the distribution of the electricity around the system and operation of the majority of the plant within the substations will remain under the central control of the Power Engineers Department. Effectively, the boundary between the Line Control and Power Control will be the outgoing breakers on the 415V ac and 630V dc busbars.

Central Line SCADA

The Central Line has undergone an extensive £750M modernisation during the period 1988 - 1995. This has replaced the rolling stock, signalling, communications and power systems.

As a result it has also been possible to re-evaluate the control philosophy, challenging traditional solutions and ultimately providing modern control equipment with all the advantages of high availability, flexibility of location and subdivision/revision of roles and responsibilities.

The Central Line has been provided with a new SCADA system consisting of two control centres, the Power Control Centre and a power operations desk within the Line Control Centre. The substations are equipped with RTU's to enable remote control and monitoring of all equipment through any one of the control centres.

With the implementation of such a SCADA system, the methods used to control and monitor the power network have been enhanced, and ensures that the current safe method of operation is maintained. Safety of system operation, especially that of the dc traction system, is considered of paramount importance for LUL.

Additionally, the hardware configuration adopted provides a higher integrity than the existing system and provides flexibility to enable additional RTU's to be added.

The hardware configuration of the Central Line SCADA system is shown in Figure 1.

Each control centre comprises LAN based computer systems consisting of main and standby PC servers and dual front end PC communications controllers. These are all UNIX based machines with the exception of the MIS PC which is windows based.

The workstations are also PC based and drive 21" colour VDU screens which provide the operator interface to the system.

The data to and from the RTU's is passed on dual communications lines to the front end multiplexers at each control centre. Each multiplexer and front end communications controller PC is duplicated and, in the event of failure, automatically switches to the standby PC or channel.

The main server acts as the main database and controller for each control system while the standby maintains a mirror image of the main database. In the event of failure the standby server automatically takes over control.

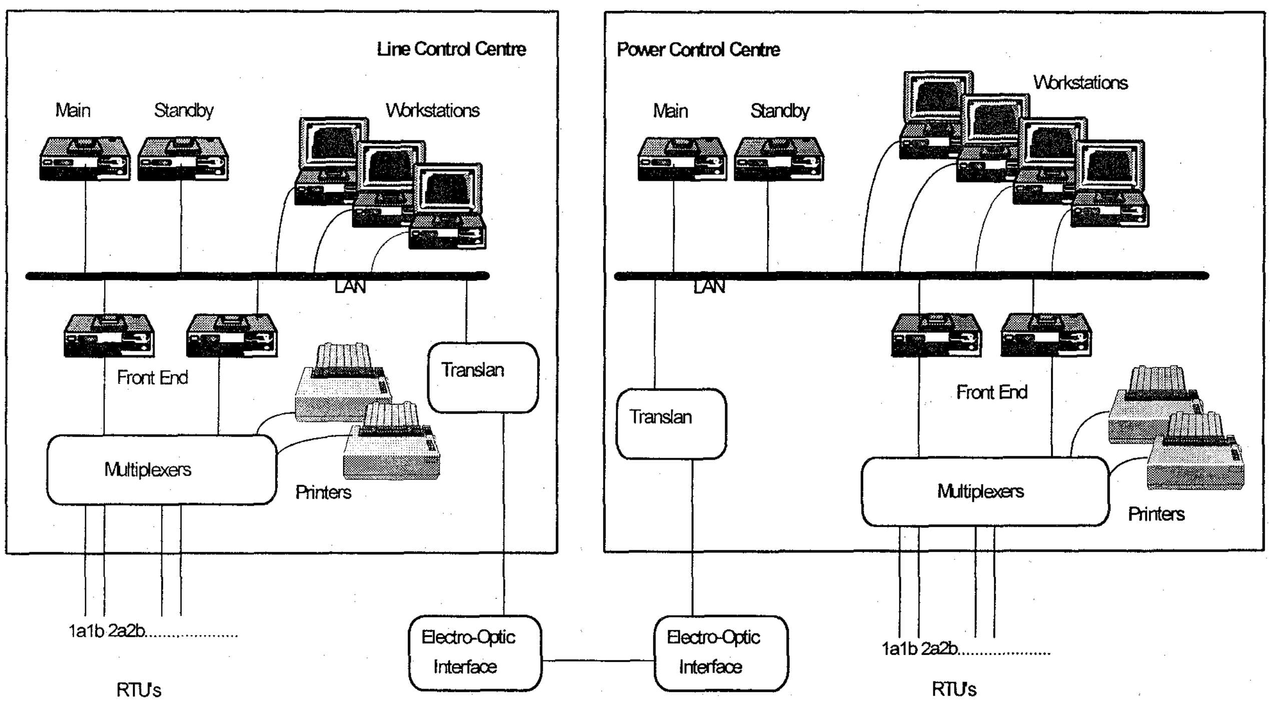

Figure 1 - Central Line Configuration

In the event of the dual communication line failure between a RTU and a control centre, control and data can be accessed from one control centre to another by switching a workstation to the other control centre via the LAN to LAN link. This link is also used to ensure that any changes made at either control centre are

always transferred to the other control centre.

Three workstations are provided at each control centre. Two are used as the operator interface and consists of an industry standard VDU, mouse and keyboard. The third is the engineers workstation and is used for data maintenance, picture modification etc. and consists of a VDU, digitiser and keyboard. A fourth Workstation is provided at the PCC for MIS and archiving.

The installed HMI was semi-graphic, however, during the course of the Contract this was upgraded to a full graphics system following the release of new software by the supplier.

Both control centres have UPS for backup in the event of power supply failure.

The Central Line SCADA system has been designed to provide a high integrity and availability for the operation of the Central Line.

The dual control centres are identical in operation and have facilities to enable control and monitoring of all aspects of the Central Line Power System. However, in normal operating mode each control centre has a particular 'Area of Interest'.

It is planned that the power system will be operated on a devolved control basis with the PCC being responsible for the control and monitoring of the ac power distribution and the LCC being responsible for the control and monitoring of the dc power.

The status of the plant is available at both centres, however, control of plant items is restricted to the 'Area of Interest'. Access to a particular 'Area of Interest' is controlled by operator authorised password and in the event of transfer of control from one centre to another, the use of authorised passwords will enable control of the whole power system from one centre.

The information presented via the VDU is in two formats, graphical and alphanumeric. The graphical screens will be the substation layouts (single line diagrams) showing CB data, measurands (current etc.) and measurand trend information, and the alphanumeric will be alarm lists, event lists etc.

Entry of data, access of information and control of plant is directly from the screen information by use of a mouse and drop down menus (supplemented by the keyboard). This method ensures optimum use of the facilities available and provides a user friendly HMI.

The energy consumption of each traction substation is monitored by the SCADA System and reports for each substation and for the whole line are produced on a weekly and monthly basis and transferred to a PC for management reporting and archiving.

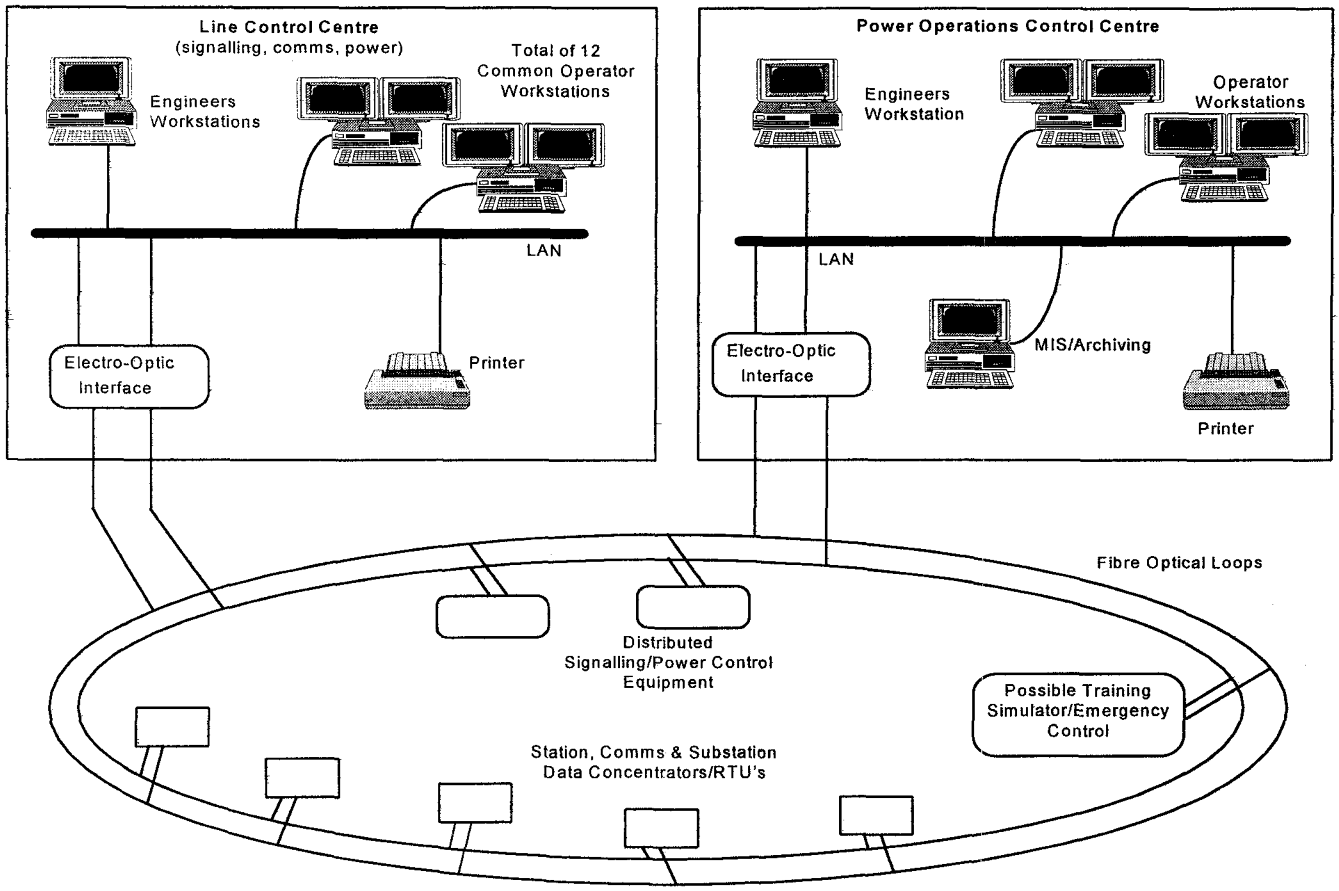

Figure 2 - Northern Line Philosophical Configuration

New Northern Line

LUL is now undertaking a comprehensive modernisation of the Northern Line, again the scope is to include rolling stock, signalling, power and infrastructure.

The overall design principle for the new Northern Line is being developed on a similar basis to that of the Central Line with a number of variations/enhancements found necessary to meet new standards and to take advantage of the experience gained on the implementation of the Central Line project.

The main communications utilise an optical fibre to provide a high integrity system backbone.

Two basic options for the SCADA system development were considered as discussed below.

Option 1 for the development of the power operations control centre for the Northern Line was the provision of two dedicated dual computer systems linked together by a optical LAN-LAN link. This was a similar arrangement to that of the Central Line.

The Line Control centre desks would be provided with space for power system SCADA HMI's and the associated telephone/communications equipment for control of the dc traction and lv station supplies.

Option 2 was for the integration the power operations SCADA within the line control centre computer system and provide access via a optical fibres to all SCADA functions at the line control centre (for all dc and for lv station monitoring and control) and at the power operations control centre for hv and the remaining lv control.

Having reviewed the advantages and disadvantages of the various options it was proposed that the integrated scheme with the line control centre and possible training simulator/emergency control centre including the power operations SCADA system, be implemented.

The HMI and security required for the operation of the power system is inherent in the design of the computer system as is the requirement for the signalling security in addition to the power operations control centre security.

This integrated arrangement is shown in outline in figure 2.

The SCADA system utilises the communications system, similar to that of the Central Line signalling system and Jubilee Line Extension, of two separate optical fibres loops with routing in each fibre being possible in either direction around each loop.

Communications from the substations will be provided on A and B channels from each substation data concentrator/RTU and will utilise separate channels in each fibre loop.

Dual optical fibre cables will also be provided between the power operations control centre and the fibre loops.

The signalling system and train data/communications control and monitoring will also utilise the dual fibre communications loops and will be connected to the signalling processors at the line control centre and the signalling equipment at the appropriate interfaces.

The main concerns in developing such a system that includes all aspects of control and monitoring is the change in operating culture for the operations personnel.

Possible Future Developments

Using the experience of the LUL line modernisation it is clear that the operational demand for improved integrated control facilities, including intelligent diagnostics, can be met by the use of technology (particularly in the communications arena). The signalling and control systems now being used in the railway environment are based on dual redundant highly interactive systems.

The authors believe that the future for the development of the Power System and the Power SCADA System is to follow the path of providing a safe and efficient method of controlling and monitoring the Power System using these tools. This will meet LUL business requirements of autonomous line control (including traction power) and, with the control of signalling and track power from one location, enhance the safe and efficient running of the line.

This philosophy enables the integration of Line and the associated Power Control and Monitoring using common HMI's, where an operator can select from one workstation the desired area which it is wished to view/operate (e.g. the dc traction power, public address system, CCTV etc.).

The system provided will be flexible enough to allow integration of any technology or system that is introduced. Additionally, flexibility of maintenance of the control system and issues relating to software control have also to be addressed.

The control system to be introduced should meet OSI standards.

It is foreseen that the use of Technology and Systems Engineering will drive this to provide common control systems for railways.

This proposed future development will use technology which is currently available and it is anticipated that the main problems to be encountered will be in the operational area where the introduction of the new philosophy for running a railway and the associated power system will require considerable operator development/training to change traditional attitudes. Indeed it is essential that the power, signalling and communications engineers agree a common philosophy and nomenclature.

Conclusions

The development of technology, particularly in the communication and control arena, has enabled the migration of control onto one system. In multi-discipline environments such as the railways this has led to the development of the 'systems engineer' and the use of systems techniques. This approach enables synergistic benefit to be driven out of the sum of the individual systems.

Over the last 50 years LUL has developed a power control philosophy based on the technology available. This control philosophy must now change to meet the new operational requirements to maximise the benefits of new technology. The changes will be far reaching covering nomenclature through to a revision of roles and responsibilities.

It is essential that power, signalling, and control engineers in general get together to understand their respective needs and develop a common control philosophy for the railway environment. The authors feel that this approach is also essential for the development of any control system in any industry.

It is believed that the proposed integration of power, signalling and communication control and monitoring using a common architecture with common HMI is in the best interest of the railway, however, believe that the biggest hurdle to be overcome is not one of technology but one of culture.

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