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Application Note

AN03.2

Tunnel Communications Services

Introduction

Mine Radio Systems has a long established history of providing communications systems for confined spaces in the toughest and most arduous of all environments – underground mining. With decades of combined experience in the design and installation of two-way VHF and UHF communications systems, data and video, Mine Radio Systems can provide a wide variety of communications services in all types of tunnels.

This application note describes an integrated communications system that provides permanent voice, data and video services for operation and maintenance of an electrical distribution tunnel. Mine Radio Systems also provides other types of tunnel communications services (e.g. for Tunnel Boring Machines) during the construction phase, which are described in other application notes.

Elstree – St. John's Wood Tunnel

National Grid has a statutory obligation to maintain a secure supply of electricity across England and Wales for onward distribution by the electricity supply companies. In London, the biggest customer is London Electricity and, together with LE, National Grid is responsible for ensuring that they deliver precisely the right amount of power that people need. The demand for electricity in London is growing and as some of the National Grid equipment was installed in the 1960s, it needs upgrading. National Grid is implementing plans to meet increasing demand for at least another 20 years, using the latest and most efficient equipment available to the Company.National Grid is undertaking a major civil engineering project - *The London Connection* - to ensure that all its customers (the largest being London Electricity) can meet the ever-increasing demand for electricity in and around London.

At 20 km long and 3 metres in diameter *The London Connection* is the largest tunnelling project that National Grid has ever undertaken. The construction of this tunnel will avoid the necessity of erecting new 400 kV electrical distribution towers.

Two new 400 kV substations are being built at Elstree and St John's Wood (both extensions of existing substation sites). In addition, five intermediate tunnel access shafts and head house buildings will be sited along the tunnel route located in Centennial Park, Canons Corner, Colindale, Cricklewood and Kilburn. These buildings will be needed for ventilation purposes and for the control equipment needed for the operation of the transmission cables.

The route of *The London Connection* will connect Elstree, Hertfordshire to St John's Wood in North West London. The 20 km tunnel will run beneath the A5 motorway, with new 400 kV substations at either end.

There are five intermediate ventilation and access points along the route at Centennial Business Park, Canons Corner, Colindale, Cricklewood and Kilburn Grange Park.

Elstree is the starting point of *The London Connection* where the new 400 kV circuit will be connected into the rest of the high-voltage transmission system in England and Wales.

The new 400 kV sub-station required for *The London Connection* will be built within National Grid's existing site at Elstree. An additional head house building and shaft will be situated within the neighbouring field to the south east of the site, the latter being for ventilation purposes and access to the tunnel for ongoing maintenance.

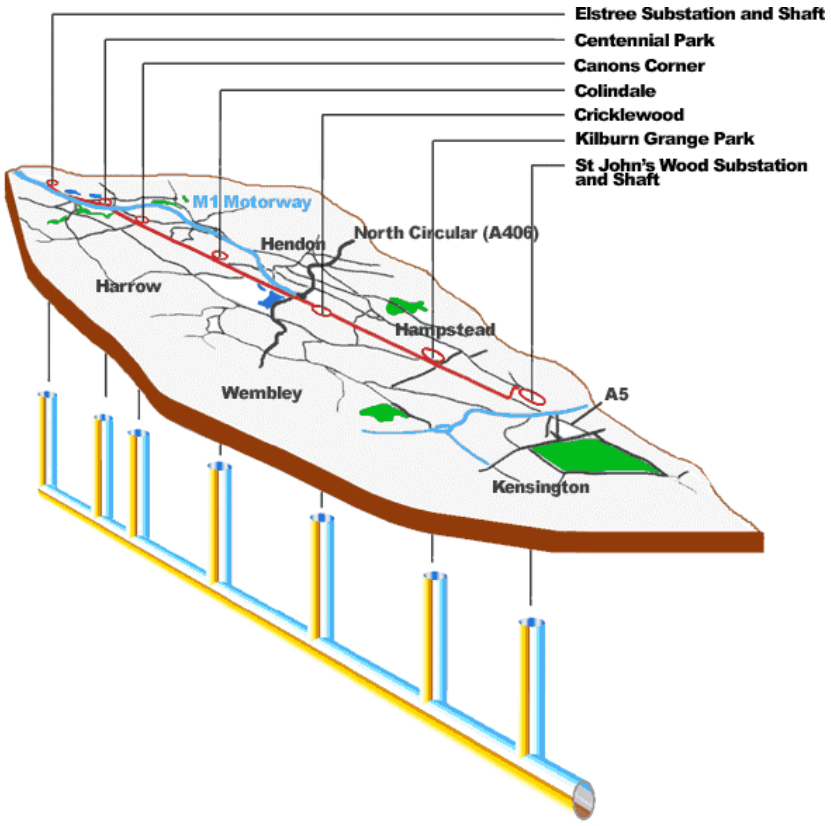

Figure 1: Tunnel route for *The London Connection*

The Elstree shaft and the 20 km tunnel were completed by July 2001. The head house will be constructed by early 2003 and the new substation by early 2005.

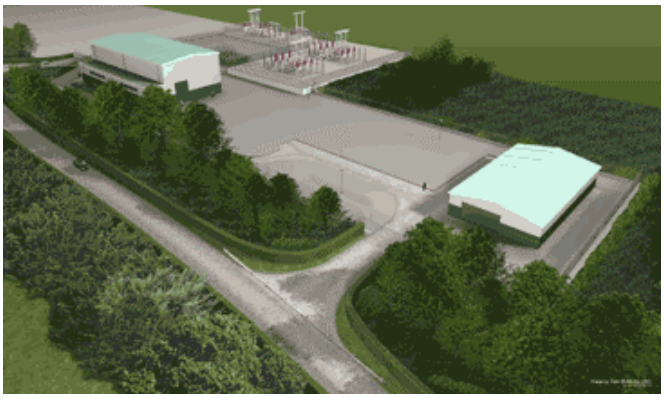

Figure 2: 400kV substation and head house at Elstree.

Figure 3: The Tunnel Boring Machine in the shaft at Elstree. Weighing 80 tonnes, the TBM advanced at approximately 150 m per week.

Figure 4: Inside the completed tunnel from Cricklewood to Canons Corner. National Grid's 20 km Elstree to St John's Wood cable tunnel was constructed within a 12-month period using three (3) tunnel boring machines.

Figure 5: Construction of the new 400 kV substation and removal of the Tunnel Boring Machine after completion of the section of tunnel from Cricklewood to St John's Wood.

The St John's Wood access shaft was completed at the end of June 2000 and took three months to build. Work commenced on the new substation in October 2000 and is due for completion by late 2004. During 2003 and 2004 modifications to the existing site equipment will be undertaken to allow the gradual commissioning of the new 400 kV sub-station by the end of 2004.

A web site at www.thelondonconnection.co.uk is dedicated to the construction of this tunnel.

General Description

Mine Radio Systems was sub-contracted by J. Murphy & Sons Limited (a major UK tunnelling contractor) to design, engineer, furnish and commission the communication systems for *The London Connection*. The voice communication requires a fully redundant configuration where any single component failure will not affect system operation. Video and data communications are provided for operation of four monorail vehicles inside the tunnel for the inspection of the 400 kV cables. To meet the stringent system performance requirements, state-of-the-art technologies are used in the communication systems.

Features of the systems include

- Three voice channels, four data control channels and four video channels
- Only passive components inside the tunnel
- 1-5/8 inch diameter leaky feeder cables
- Voice system redundancy against any single component failure or damage to the cable
- Redundant routes for voice and RF signals over fibre / leased lines
- Data networks with fibre and wireless transmissions
- Digital video over IP for remote visual monitoring
- Voice over IP for the voice system archiving and recording

The system is designed to provide continuous voice communication in the case of a single component failure. The tunnel radio coverage is provided through the two sets of radio transmitter / receivers at St. John's Wood and Elstree and distributed along the length of the tunnel by fibre optic cables with optical lightwave (LW) to RF conversion at each of the seven shafts.

The operation of the VHF and UHF radios are monitored for proper system operation via a SCADA PLC.

When any VHF base radio is keyed up for transmission, the RF power output of the radio is monitored. The LW/RF units are also monitored for proper operation. If any of the radios or LW/RF units are faulty, an alarm is send to the PLC which then activates the alternate base station transmitter equipment to by-pass the faulty unit, providing continuous system operation with any single equipment failure.

At Elstree and St. John's Wood, a test transmitter controlled by the SCADA system is installed to check the performance of the base receivers. A receiver fault is sensed through the SCADA system and an alarm is generated.

Any leaky cable fault will not affect the voice system operation as all the signals are fed from both ends. The system design provides adequate RF signal strength in the worst case situation where the cable damage is at a shaft and the RF signal needs to be routed to / from the adjacent shaft.

Any damage to either the main or alternate fibre optic cables is detected in the lightwave unit(s) as "loss of lightwave signal". The operation of the system is continuously monitored by the SCADA PLC. In the event of an alarm the damaged fibre optic cable is bypassed and the alternate cable used instead.

In addition, there are four leased lines that have been installed between St. John's Wood and Elstree control rooms. In the event of damage to both the main and the alternate fibre cables, the leased lines are switched in automatically by the SCADA PLC.

All the fixed radio equipment in the system is powered by back-up battery with six hours of operating capacity after loss of AC power or power supply failure.

The computers and control equipment are powered by UPS units, with six hours capacity. If a UPS fails, the AC mains are connected directly to the equipment and an alarm is sent to the SCADA PLC.

The RF signals at each shaft are combined and distributed through RF combiners / splitters. This approach provides the highest possible reliability and eliminates the downtime due to RF switch failure that is characteristic of some other designs.

A redundant configuration is used where each received audio signal is processed by dual modules, so that if one fails the other will automatically take over. There is no impact on the system operation if one of the voter modules fails. It is necessary to test the receiver voter modules periodically as part of the preventive maintenance schedule as these modules are not monitored by the SCADA PLC.

The RF filters are passive devices and have a high MTBF. As such it is not necessary to use redundant RF filters. The failure of an RF filter affects one shaft only while system operation is maintained at adjacent shafts. It is necessary to test these RF filters periodically as part of the preventive maintenance schedule since these modules are not monitored by the SCADA PLC.

Failure of an audio bridge will affect one voice channel only. The other channels remain operational. It is also noted that the audio bridge has a high MTBF. Failure of an audio bridge would be observed due to the loss of the audio signal. However, these audio bridges should be tested periodically as part of the preventive maintenance schedule.

Failure of a control console will affect only that position while the other control console remains operational. For the affected position, the control room operator can use a hand held radio to continue operation. In this case, the hand held radio will be programmed to scan the other channels while the operator is communicating on one channel. Failure of a control console is usually observed immediately due to loss

of audio signal. However, the control consoles should be tested periodically as part of the preventive maintenance schedule.

Fibre Optic Distribution

The voice channel LW/RF distribution system is operated through fibre optic cables. It is configured as two star networks, one with St. John's Wood base radio site (control room) as the hub and the other with the Elstree base radio site (control room) being the hub. The seven shafts are each connected to the hubs.

The two base radio RF signals at St. John's Wood control room and Elstree control room are sent via the fibre optic cable to and from the shafts at St. John's Wood, Kilburn Park, Cricklewood Siding, Colindale, Canon's Corner, Centennial Park and Elstree for transmission to/from the tunnel through the leaky cable.

These shafts are normally connected to the base transmitters at St. John's Wood. Elstree base transmitters will be switched in automatically upon detection of St. John's Wood transmitter failure. Switching control is provided by the SCADA system.

The base radio receivers are connected to all the seven shafts at all times, the receiver voting equipment will select the best overall received signal.

The data channel LW/RF distribution system is operated through fibre optic cables. It is configured as two star networks, one with St. John's Wood base radio site (control room) as the hub and the other with Elstree base radio site (control room) being the hub. Connected to the hubs are all the seven shafts. The data channel lightwave equipment is separate and independent of the voice LW/RF distribution network.

For each data channel (one for each vehicle), the base radio is configured as a warm-standby space diversity radio with two transmitters and two receivers. The main base transmitter is connected to the four shafts. When the main transmitter fails, the standby base transmitter replaces it automatically.

The side A and side B receiver units serve alternating shafts. Interconnection of these intermediate shafts to the base radio receivers at St. John's Wood and Elstree is shown in the table 5.1.2 below:

One fibre terminal is installed at St. John's Wood and one at Elstree. Two fibre pairs run through the tunnel and connect the two fibre terminals.

The communication channels provided between St. John's Wood and Elstree through the fibre system are:

- 2 Ethernet channels at 10 Mbps data rate. These channels carry the vehicular video signals and voice recorder signals between the Elstree and the St. John's Wood computers.
- 4 data channels at 9.6 Kbps data rate. These channels carry the vehicle monitor and control signals.
- 4 4-wire E & M signalling channels where 2 channels carry the 2 voice radio signals and 2 channels linking the 2 control consoles.

Voice Communications

All receive signals are routed to a receive voter at St. John's Wood which selects the better voice quality of the two received signals before feeding the signal to the audio bridge. The audio bridge then distributes the received audio signal to:

- Two base radio transmitters for re-transmission into the tunnel via the LW/RF network & leaky cables.
- The voice recorder.
- The control consoles at St. John's Wood and Elstree.

The audio signal from the control consoles is routed via the audio bridge to:

- The 2 base radio transmitters.
- The voice recorder.

There is no audible signal from the voice recorder.

At each control console, a PABX telephone line is available, which can be patched on a selected radio channel manually. The telephone lines are not routed through the audio bridges. The E and M signalling is configured in a similar manner.

The transmission from a mobile handset is coupled to the leaky cable, which is fed to the base receivers via the LW/RF units. The transmitted audio signal is recovered at the radio receivers at both sites and is sent to the voter via the fibre terminal. At the same time, the radio receivers also provide a control signal (E lead) to the audio bridge upon detection of the mobile handset signal.

The better of the two received audio signals, as selected by the voter, plus the M lead control are distributed through the audio bridge to the base radio transmitters at St. John's Wood and at Elstree. The St. John's Wood transmitter is keyed up through the M lead to re-broadcast the audio signal at all seven shafts via the LW/RF units. If the St. John's Wood transmitter fails, the Elstree transmitter is keyed up instead, through the switch over panel, under the control of the SCADA system.

The radio transmission is routed throughout the tunnel via the leaky cable and received by all mobile handsets.

The signal from the transmitting mobile handset is routed to the St. John's Wood receiver voter. The received audio is then distributed by the audio bridge to both the St. John's Wood and Elstree control centres where the transmission can be heard over the control console loudspeakers.

Transmission from a control centre is broadcast to all seven shafts and the other control centre, through the audio bridge. The mobile handsets receive the transmission via the shaft base transmitter and leaky cable.

All radio system voice transmissions, including radio transmissions from the mobile handsets, the control centres and telephone callers (via the telephone interconnect unit) are routed to the voice recorder through the audio bridge. The voice recorder applies the date/time stamp on the recording of the voice transmissions for replay and analysis.

Display, replay, archiving and management of all voice logs are handled through the voice recording server and client workstation as computer files.

At each of the two control consoles, a telephone line is available for interconnection to one of the two selected radio channels. This telephone patch is manually activated by the control console operator to establish a connection between the radio channel and a telephone set on the PSTN network.

Network Communications

Two 10 Mbps Ethernet networks are installed, one for the vehicular video signals and the other for the voice recording. These networks provide data communication amongst the following pieces of equipment:

The video network:

- The two computers at St. John's Wood for the vehicular video signals.
- The two computers at Elstree for the vehicular video signals.
- The four vehicular base data radios.

The voice network:

- The computer at St. John's Wood for the voice recorder functions.
- The computer at Elstree for the voice recorder functions.
- The voice recorder module.

The two data networks are interconnected between St. John's Wood and Elstree, over two fibre Ethernet channels.

The data communication over this Ethernet network utilises TCP/IP protocol with unique IP addresses assigned to each and every piece of equipment in the network.

Video Communications

The video signal from the selected (one of the two) vehicular camera is converted to a digital signal by the vehicular video server and transmitted by the UHF radio in the vehicle. This UHF signal is picked up by the leaky cable and fed via the LW/RF units to the data base station radio. The digital video signal is recovered by the base UHF radio and sent to the video control computer at St. John's Wood or Elstree for display and distribution. A dedicated software application is available to display, replay, archival and management of all video signals.

Each UHF vehicular radio, base radio, computer and vehicular video server has its own unique IP address, conforming with the TCP/IP Ethernet protocol.

Each vehicle UHF radio operates on its own RF channel, with a corresponding base radio.

For Further Information

If you require clarification of any of the above notes of have any comments or suggestions relating to this or other application notes from Mine Radio Systems please call your nearest Mine Radio Systems distributor or agent.

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