Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

Computer aided remote condition monitoring of railway assets (Level crossing barrier case study)

H.R. Yazdi[1], C. Roberts[2], C.J. Goodman[2]
[1] *Federal Mogul Technology, Rugby, UK*
[2] *School of Electronic and Electrical Engineering*
The University of Birmingham, Birmingham, UK

Abstract

The safe, efficient and reliable operation of railway infrastructure is dependent on the state of health of a number of sub-systems. The ability to predict failures in these sub-systems is paramount to the operation of a cost-effective and delay-free rail network. In order to work towards achieving this goal it is necessary to introduce remote condition monitoring systems coupled with a proactive maintenance regime such as reliability centred maintenance. Once these systems are in place the following functionality can be achieved:

- ❑ Incipient failure prediction;
- ❑ Post incident analysis;
- ❑ Generation of site/network specific operating statistics;
- ❑ Failure diagnostics;
- ❑ Reduction of delays and hazards.

In 1997 The University of Birmingham together with six industrial partners commenced a research project entitled Reliability Centred Maintenance and Remote Condition Monitoring for Railway Signalling Equipment. The project takes a Level Crossing Barrier (LCB) system as a case study and aims to recommend and develop systems of work, instrumentation and fault detection algorithms capable of achieving the above functionality.

In this paper the authors will discuss progress with the project to date, particularly concentrating on the areas of instrumentation and software developed.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

1 Introduction

The restructuring of the railway network in the United Kingdom has led to an increased pressure for a rational approach to infrastructure maintenance. During the late 1980's Cost Effective Maintenance (CEM) was introduced. CEM was based on preventive maintenance, which entailed minor component exchanges after an arbitrary period of time and major component overhauls for large systems such as diesel engines. At the same time, maintenance operations that had traditionally been incorporated within major examinations that took equipment out of service for several days were replaced by frequent minor inspections; this significantly improved the availability and cost-effectiveness.

Condition monitoring provides a rational basis for supplementing, and over time improving, an existing maintenance regime. There are a number of condition-monitoring systems currently in use in the rail industry, descriptions of which have been reported by Roberts and Fararooy [1]. Systems have been introduced to condition monitor a whole host of assets from bridge integrity after a vehicle 'bash' to station elevator performance. However, until recently these systems have lacked any kind of active intelligence to determine whether maintenance should be carried out. Fararooy and Allan [2] have stated the benefits associated with active condition based maintenance for railway signalling equipment. Their work gives an overview of railway maintenance and addresses when condition monitoring would add value to existing methods of work. They state that it is imperative that condition monitoring should:

- not add on an extra burden to the process or plant being monitored;
- be user friendly and easily operated;
- be robust and capable of distinguishing between actual incipient failure and natural small drifts;
- be reliable and repeatable.

Other than the academic work underway, there are a number of commercial data acquisition systems, which have been used for condition monitoring of railway assets. The "Trackwatch" system is installed on a number of level-crossing barriers across the UK. These existing systems monitor the open and closed status of the relay logic controlling the barriers as a function of time. The data is available via telemetry to users for analysis in the event of an incident.

Points machines have also attracted attention for remote and/or local condition monitoring research projects. Clemens [3] describes a simple time based data analysing system for prediction of failures in point machines using "Trackwatch" units. This approach uses predetermined limit values; maintenance staff are notified via a pager if these limit values are exceeded.

AEA Technology Rail has developed a number of condition monitoring systems such as OLIVE which can be used for monitoring of overhead wire catenary systems. Phillpotts [4] describes the performance of OLIVE as successful. However it is noted that further development work is required for data processing in order to achieve intelligent condition monitoring.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

2 The level crossing barrier (LCB) system

Level crossings are typically installed either where it has not been economical to construct a bridge or where the terrain surrounding the railway has resulted in difficulties with bridge construction (e.g. a very flat terrain). In the UK there are approximately 5,000 level crossing installation. This paper will mainly consider the type BR843 electro-hydraulic barrier systems, which account for around 50-60% of installations.

To raise the boom, the BR843 uses a rotary hydraulic pump that is driven by an electric motor. The pump delivers oil under the piston of a jack directly coupled to the boom. A relief valve determines the maximum pressure that can be produced in the system. It is possible to hand operate the barrier using a telescopic lever operated pump by switching the barrier from the '*automatic*' to the '*manual*' operation.

Once raised, a solenoid valve is energised which traps the pressurised oil under the jack piston. On removal of current from the solenoid coil, the barrier opens and the trapped oil evacuates back into the tank, therefore lowering the boom. The jack is provided with a damper that decelerates the lowering of the boom over the last 10° to restrict bounce.

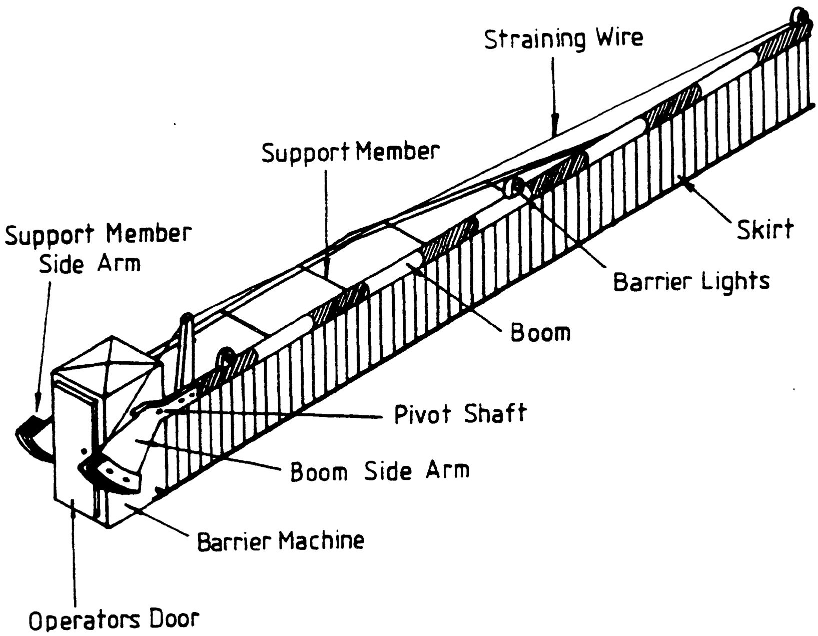

Figure 1: The external view of an MCB barrier machine

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)

The operation of the crossing is repeated to the supervising signal box in the form of an indication showing:

- 'Barriers Raised' - when the line is clear;
- 'Barriers Working' - when the barrier sequence is operated;
- 'Barriers Failed' accompanied by an audible alarm - if the barriers remain lowered for more than the specified time;
- 'Power Failed' accompanied by an audible alarm - if the power has failed and the crossing is using its high capacity battery. This warning is also used to indicate the charging of the battery has ceased.

Currently, maintenance of level crossings is either scheduled (calendar based) or corrective (fire fighting). In the UK a minimal maintenance schedule is carried out quarterly (LD11A) with an annual overhaul (LD11B).

The scheduled maintenance regimes are carried out uniformly regardless of the current operating performance or frequency of operation of the site. The schedules contain a number of preventive component replacements (e.g. brushes) as well as oiling and visual inspections.

Corrective maintenance is only carried out once the system has failed. Often the failure may cause delays to trains resulting in substantial fines levied on the maintainers. Statistical research shows that the Mean Time Between Failure (MTBF) of an LCB system is approximately 1 month and that 75% of sudden failures result in minor maintenance and 25% require a major overhaul of substantial component replacement (e.g. entire pump unit).

By optimising the amount of time between maintenance a more efficient and effective system of work can be introduced. Reliability Centred Maintenance (RCM) recognises that the current condition, operating statistics and environmental condition are different at most sites. RCM therefore suggests either on-condition maintenance or preventive tasks that are site dependent with optimised timings between any required site visits.

3 Condition monitoring of the level crossing barrier

In order to be able to remotely evaluate the condition of health of an LCB (or any other assets), it is necessary to acquire and analyse a number of system parameters using appropriate transducers. These parameters are categorised as either condition, operational or environmental, directly correlating with the variables of RCM. The parameters acquired for the LCB are shown in Table 1.

Condition Data	Operating Statistics	Environmental Issues
• Motor Current • Supply Voltage • Hydraulic Pressure • Barrier Movement • Battery Voltage	• Digital Relay Contacts	• Operating Temperature • Wind Speed • Wind Direction

Table 1: Condition, operational and environmental parameters measured

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

Issues relating to parameter selection include – monitoring of parameters affected by failure, ease of measurement non-invasively, cost of transducers, the ability to carryout parameter estimation.

If it is not possible to measure a system parameter, such as hydraulic flow, these parameters can be calculated explicitly from formulae or using parameter estimation techniques.

Collecting the data from various transducers installed throughout an LCB installation using traditional serial point-to-point links is not practical due to the excessive amount of cabling and the 'noisy' environment. With this in mind alternative methods for distributed data acquisition were sought.

FieldBus is a highly flexible, reliable communications network which offers high performance characteristics (typically 1 to 5Mbit/s) at 1m to 5km, robustness, low cabling usage/cost, ease of installation, expandability, low maintenance and high electrical noise immunity. In previous papers, Roberts, et al. [5] have recommended FieldBus systems for condition monitoring, after extensive investigation and usage.

For the LCB research the WorldFIP protocol has been chosen. The protocol offers the ability to communicate at high speeds over long distance (5km) with a copper twisted-pair. The protocol has an established railway usage in Europe, relatively low cost, good data integrity and repeatability.

Each analogue transducer and digital relay connection must be connected to the fieldbus network, rather like a computer local area network. The device that interfaces the transducers to the network is known as a 'node'. Each node communicates back to a main computer that controls the network using a bus arbitrator. The bus arbitrator defines when each node can either produce or consume data across the network and defines the variables that will be communicated [6]. The interface node system was developed as part of the LCB project to enable the user to have analogue or digital connectivity with signal processing capabilities across the WorldFIP network.

Power is supplied to the node (and sensors) using the fieldbus cables. Generic supplies are regulated to supply active and bipolar sensors. Figure 2 illustrates the connection of locally distributed fieldbus networks together with their telemetry capabilities. It should be noted that this design has a generic nature that can be utilised in any configuration for any asset.

4 Software Development

After selection, development and installation of the required hardware, it is necessary to develop robust and reliable software with the following capabilities:

- ❑ Robust, repeatable data acquisition;
- ❑ Constant monitoring of vital parameters;
- ❑ Suitable Graphical User Interface (GUI);
- ❑ Report generation;
- ❑ Modular fault detection capabilities.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

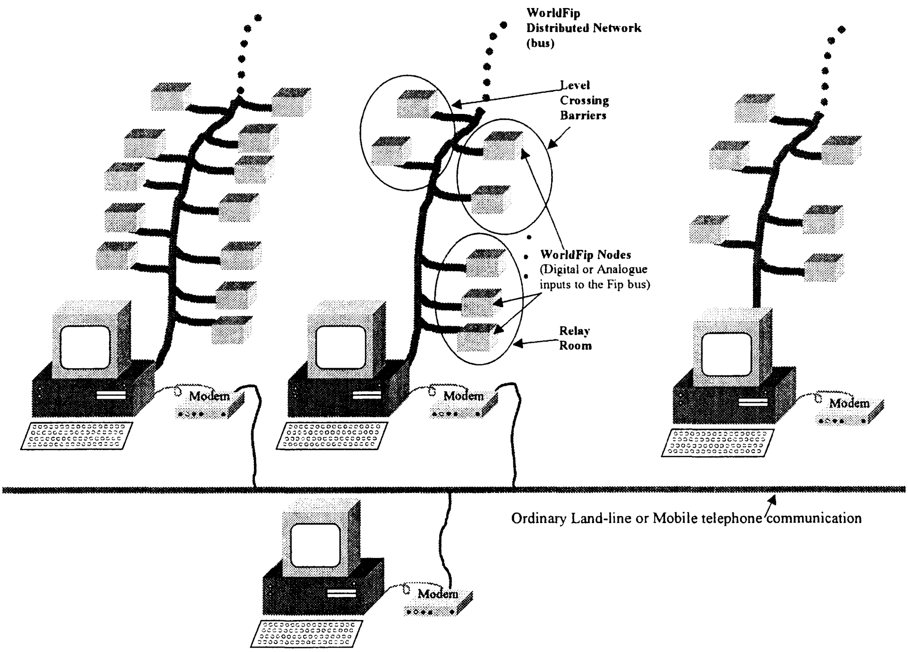

Figure 2: Locally distributed network and telemetry connection

LabVIEW, from National Instruments, was utilised to develop the WorldFIP data acquisition control that comprises variable declarations, network timings and bus arbitration. The WorldFIP routines were then used as part of a larger LabVIEW Virtual Instrument (program) that offers a dedicated GUI, reporting and 'plug-in' fault detection algorithm facilities. The structure of this design is shown in Figure 3. Figure 4 shows the GUI for the condition monitoring software that can be viewed remotely. It can be seen that the maintainer is able to check boom movements, relay switching and electro-hydraulic parameters in real-time across the telemetry link.

In addition a separate virtual instrument, which is capable of saving the data at a variable-sampling rate (5ms to 5mins), was developed. This was necessary due to the large amount of data being logged, and the region of interest in the data is the dynamic movement of the boom. The software therefore allowed for different sampling rates during different phases of the operating sequence.

Due to the necessity to carry out modular fault detection data was saved in hourly, comma separated variable text files. The research team is aware of the drawbacks of this approach, such as huge data file size and redundant data being recorded unnecessarily. However the main advantage of this approach is its compatibility with other third party software packages such as MathWorks' Matlab.

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

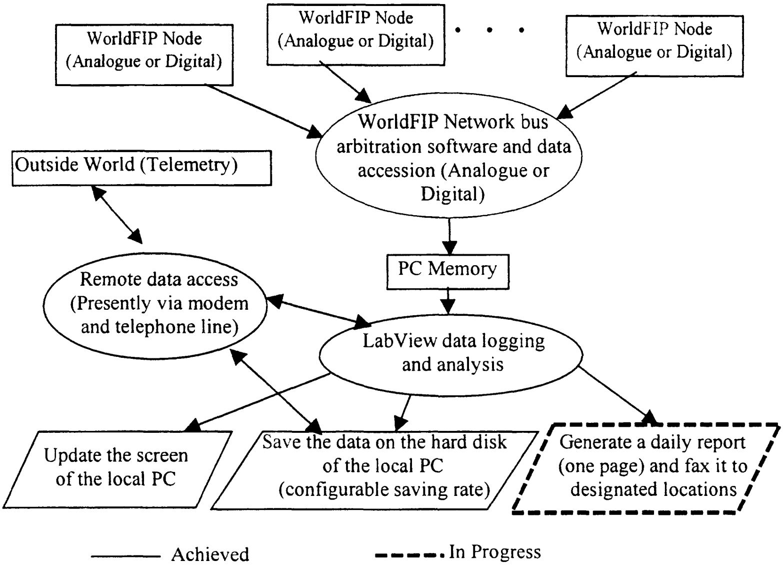

Figure 3: LCB condition monitoring software structure

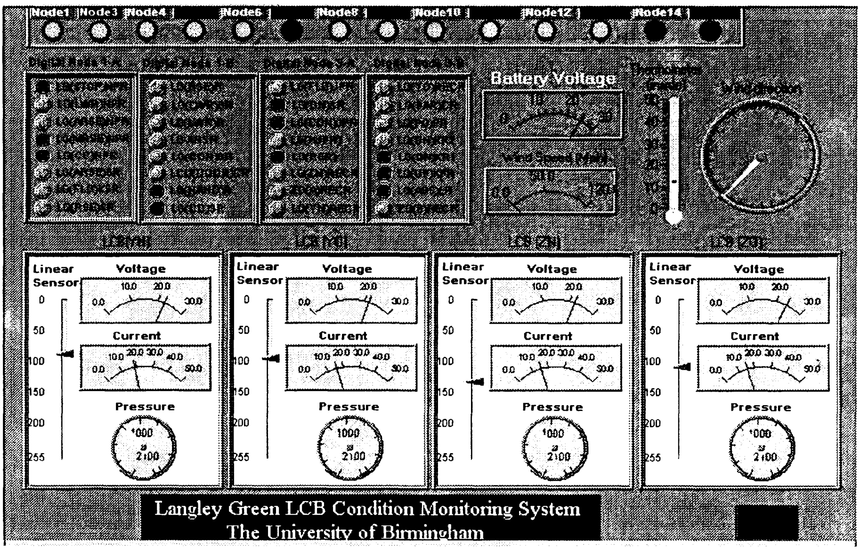

Figure 4: The LCB real-time GUI

Computers in Railways VII, C.A. Brebbia J.Allan, R.J. Hill, G. Sciutto & S. Sone (Editors)
© 2000 WIT Press, www.witpress.com, ISBN 1-85312-826-0

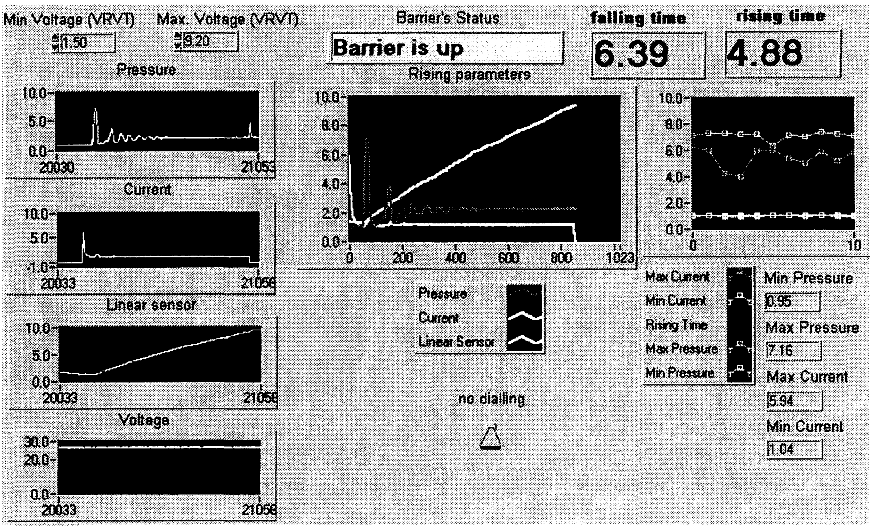

Figure 5: Simple statistical evaluation software

5 Sample results and further work

Presently it is possible to monitor remotely five 'live' test sites at Manchester (x2), Birmingham (x2) and Hull in the UK. Due to the sensitivity and confidentiality of the acquired data, every site has its own password protection. The authorised personnel can either monitor, download or analyse data from the sites remotely. A level crossing engineer, for instance, is able to observe some basic parameters and conclude that a failure is imminent.

Simple data evaluation software based on feature extraction and statistical analysis is currently being carried out real-time, on-line. However, extensive further work is planned to generate modular Matlab based fault detection routines that can be interface with the existing software in real-time. The techniques are currently being applied post-incident at the University with moderate success. These algorithms use a mixture of logic, signal-processing techniques (FFT, wavelet), mathematical modelling, fault detection and artificial intelligence techniques to predict incipient failures. The ability to demonstrate the prediction of failure robustly with integrity will result in the rational method of maintenance that is sought.

Further work is also planned to migrate the generic lessons learnt to assets such as track circuits and both electric and electro-hydraulic driven point machines.

6 Conclusions

A remote condition monitoring system has been successfully developed and implemented at a number of sites throughout the UK. The distributed fieldbus data acquisition network has proved to be robust and reliable with significant cost and performance enhancements over traditional methods. Presently five sites totalling 24 level crossing barriers are equipped with the developed system.

7 Acknowledgements

The authors wish to acknowledge the support of the Engineering and Physical Sciences Research Council through a LINK-Inland Surface Transport research grant. Thanks are also extended to the research group's technician, Andy Dunn, for his valued contribution to this work.

8 References

[1] Roberts, C. & Fararooy, S. Remote condition monitoring into the next millennium. *Proceedings of the 6th Int. Conf. on Computer Aided Design, Manufacture and Operation in the Railway and other Advance Mass Transit Systems,* September 1998.
[2] Fararooy, S. & Allan, J. Condition-based maintenance of railway signalling equipment. *Proceedings of the International Conference on Electric Railways in a United Europe*, March 1995.
[3] Clemens, K. Analysing and predicting failures in signalling and points machines using only simple time based data. *IEE Seminar on Condition Monitoring for Rail Transport*, November 1998.
[4] Phillpotts, R. Monitoring discontinuities in the 25 kV overhead. *IEE Seminar on Condition Monitoring for Rail Transport*, November 1998
[5] Roberts, C., Yazdi, H. & Fararooy, S. An intelligent fault detection system using fieldbus technology. *Condition Monitor*, December 1999.
[6] Nash, N. & Roberts, C. Condition monitoring of level crossings – event recorders to (RCM)^2. *Proceeding of the IRSE ASPECT '99 Int. Conf.*, September 1999.