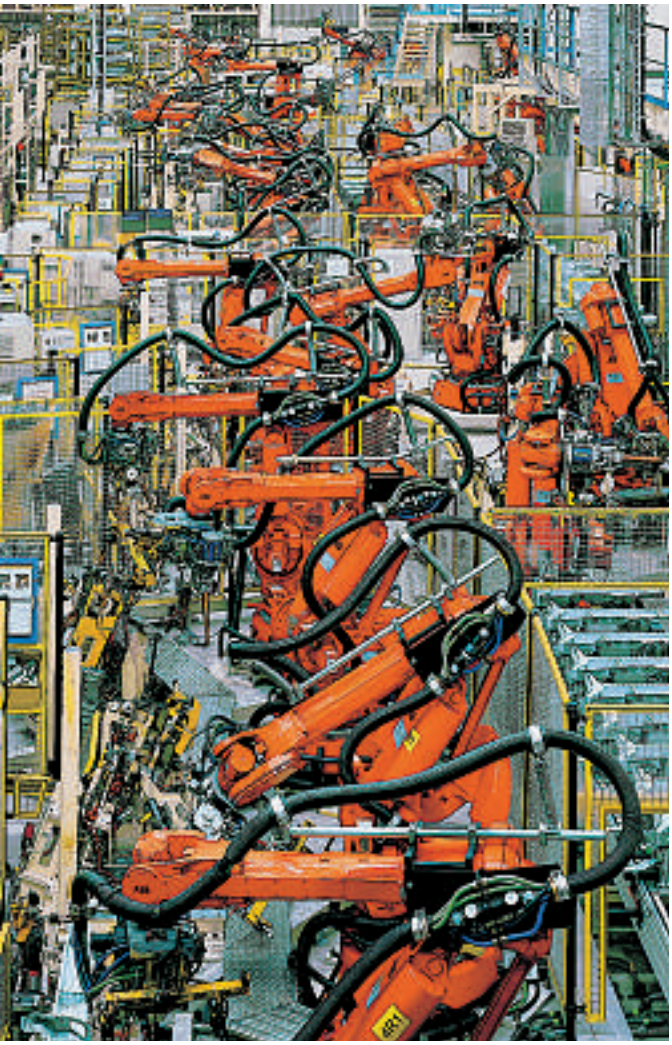


Automakers and their Tier 1 suppliers are among the companies that can benefit from dedicated Robot Condition Monitoring services.

Optimize^{IT}

Robot Condition Monitoring Tool

René Nispeling

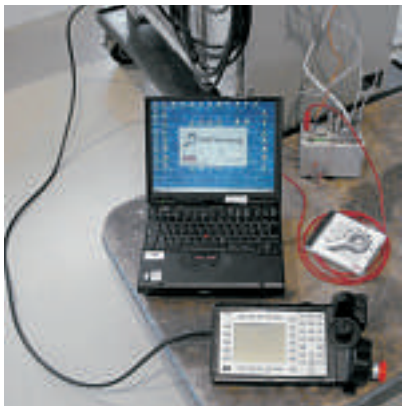
As robots have gained more and more 'humanlike' capability, users have looked increasingly to their builders for ways to measure the critical variables – the robotic equivalent of a physical check-up – in order to monitor their condition and schedule maintenance more effectively. This is all the more essential considering the tremendous pressure there is to improve productivity in today's global markets.

Developed for ABB robots with an S4-family controller and based on the company's broad process know-how, Optimize^{IT} Robot Condition Monitoring offers maintenance routines with embedded checklists that give a clear indication of a robot's operating condition. It performs semi-automatic measurements that support engineers during trouble-shooting and enable action to be taken to prevent unplanned stops. By comparing these measurements with reference data, negative trends can be detected early and potential breakdowns predicted. Armed with all these features, Optimize^{IT} Robot Condition Monitoring provides the ideal basis for reliability-centered maintenance (RCM) for robots.

Companies in the discrete manufacturing and consumer goods industries, such as automakers and their Tier 1 suppliers, are constantly striving to optimize performance. Plant assets, equipment efficiency and operating costs are all continually examined, as are the conditions that affect plant lifetime. Because of its impact on productivity, robot-based automation is often the focus of special attention, and companies are ceaselessly searching for tools that reduce maintenance effort, extend life cycles and increase utilization. Driving all this is industry's unrelenting need to improve total plant availability and productivity.

Historically, robots have been mere 'mechanical' machines with limited controls and handling capacity, lacking built-in diagnostics and requiring minimal maintenance like daily greasing, cleaning and the like. This stayed so until industry, led by automakers, began to demand more functionality. Coincidentally, technological progress enabled robot builders to develop robots that were stronger and more adaptable, as well as being reliable, maintenance-free and easy to use.

OptimizeIT Robot Condition Monitoring users can quickly identify, track and respond to problems occurring during production. Lengthy trouble-shooting procedures are a thing of the past.



The need for sophisticated service tools

Clearly, robot users have a strong interest in reducing, and preferably preventing altogether, unplanned production stops. And, when a robot does fail, plant managers are understandably unwilling to accept long, and costly, fault-finding procedures, or to wait for hours until a specialist arrives to solve the problem. Sophisticated service tools like S4Anywhere, S4Remote and DDB WebWare™ were developed by ABB to relieve precisely this kind of headache (see box below).

OptimizeIT Robot Condition Monitoring was conceived in response to users' need to increase productivity, our own field engineers' need for high-tech service tools, and the opportunities being offered by the latest industrial information technologies. Specialists from ABB Corporate Research and ABB Robotics, service engineers and user reference teams from all over the world joined together to develop OptimizeIT Robot Condition Monitoring.

To understand the main benefits, it is necessary to understand that equipment effectiveness can be maximized through efforts to control and then eliminate the main losses, these being:

- Availability losses (unplanned downtime due to equipment failures, set-up and adjustments)
- Performance losses (due to reduced speed, idling and minor stoppages)
- Quality losses (due to defects in the process; rework and start-up losses)

Reliability-centered maintenance

OptimizeIT Robot Condition Monitoring is the ideal solution for reliability-centered maintenance (RCM). The purpose of RCM is to preserve or increase system reliability while reducing the cost of the maintenance procedures. Before a decision can be made on the kind of main-tenance (time-based, condition-based, etc) needed, an RCM analysis has to be carried out on the equipment and its components.

Robot condition assessment is based on the collection and analysis of equipment data. To find out whether or not 'drifting' has occurred, data are collected using a special measuring tool and plotted to determine their trend. The slope of this graph is then compared with earlier reference graphs or the manufacturer's measurements.

The monitoring system continuously tracks the relevant parameters, flags abnormal conditions and predicts component deterioration before a malfunction can occur. The advanced warning it gives allows more convenient scheduling of repairs, letting robot users shift from preventive maintenance carried out at fixed intervals to predictive maintenance based on actual equipment conditions. Incipient failures are also recognized at a very early stage, any potentially abnormal conditions being flagged.

ABB service tools

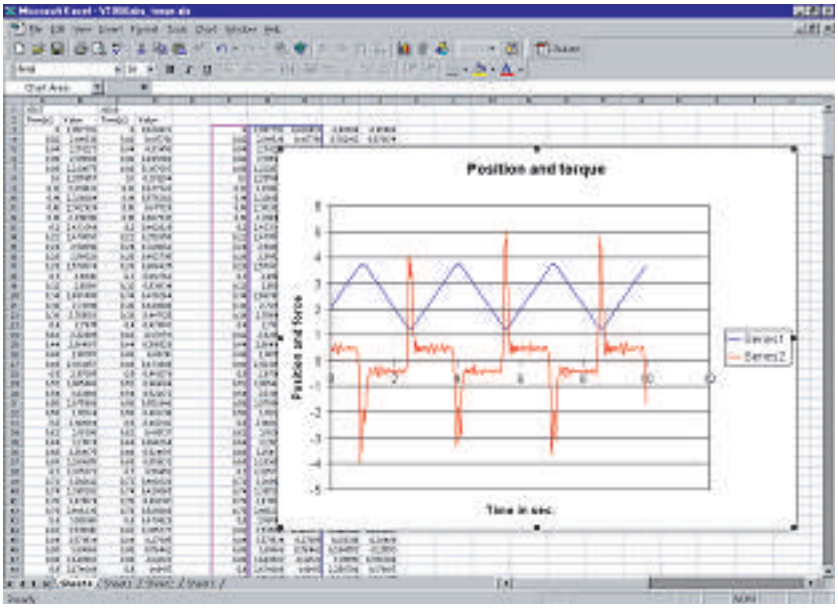
S4Anywhere: A remote guidance tool that allows ABB specialists to 'see' the robot's present status and guides the operator or maintenance engineer towards a solution.

S4Remote: An on-line tool based on ABB Webware SDK. It facilitates full access to robots for virtually every kind of remote operation.

DDB WebWare™: Solutions that allow users to continuously track production, with automatic data retrieval, logging and analysis. This focused analysis of relevant production parameters is very important for control of the production process (standard parameters are cycle time, availability, MTBF, MTTR).

Scoope®: A software solution giving an accurate picture of plant/equipment performance and improvement opportunities through measurement and analysis, and by detecting sources of loss, failure and inefficiency.

Screenshot showing the torque and speed characteristics of a robot axis during a production cycle. The blue curve shows the absolute position and the red curve the torque pattern of this axis.



MTBF and MTTR

Equipment which fails is unavailable for production, and the more failures there are the higher the unavailability. MTBF (Mean Time Between Failures) and MTTR (Mean Time To Repair) represent two ways of measuring unavailability.

Optimize^{IT} Robot Condition Monitoring was developed to increase the MTBF not only by preventing and predicting robot failures but also by learning from them, and in so doing prevent more failures. Just as importantly, Robot Condition Monitoring reduces the MTTR by speeding up fault-finding. By comparing footprints (robot characteristics) and measurements of critical variables, Optimize^{IT} Robot Condition Monitoring additionally detects any degrading of the process that could result in lower performance or quality.

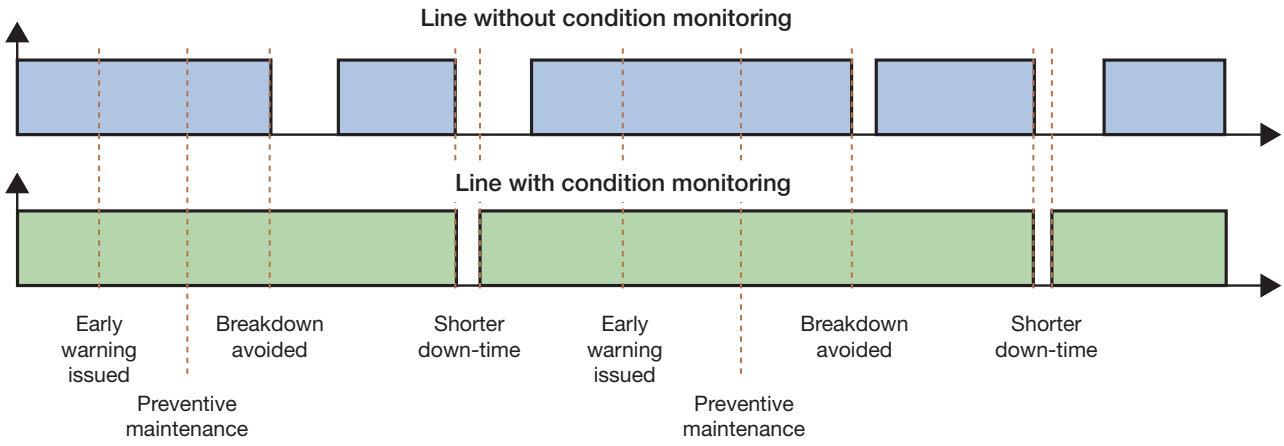
Results with condition-based maintenance methods show clearly that the utilization and productivity of production lines is significantly improved.

Optimize^{IT} Robot Condition Monitoring

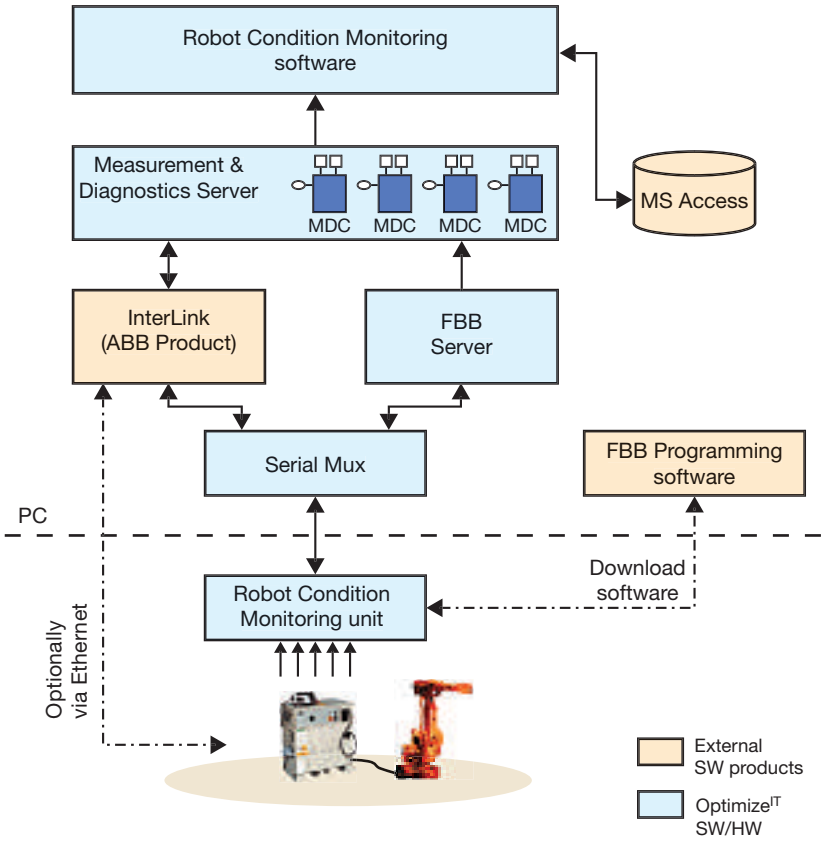
The Optimize^{IT} Robot Condition Monitoring Solution, is a portable, PC-based, user-friendly field service tool, developed by ABB for use with its robots. It consists of the following components:

- Portable PC connected to the robot controller and Robot Condition Monitoring unit
- Robot Condition Monitoring unit with dedicated cable connections to the robot main computer and critical components
- Integrated Measurement and Diagnostics Server (MDS) providing the engineer with all necessary data

Production line availability with and without Optimize^{IT} Robot Condition Monitoring. Preventive maintenance programs improve MTBF; MTTR is reduced when the right tools and procedures are used.



OptimizeIT Robot Condition Monitoring components and condition monitoring configuration. The features dedicated cable connections to all S4-family robot controllers.



Robot Condition Monitoring unit (above) and S4C robot controller (below).

■ Dedicated front-end software for on-line robot measure-ments and analysis

OptimizeIT Robot Condition Monitoring as a value-added service solution

OptimizeIT Robot Condition Monitoring will only be useful in the hands of trained specialists. Measurements and graphs need to be interpreted and compared with references, while up-to-date maintenance and trouble-shooting information can only be obtained from the ABB intranet knowledge database. Each installed OptimizeIT Robot Condition Monitoring tool helps to fill this database over time with more field information. This tool is therefore offered to ABB robot users as part of a service agreement and operated by trained ABB engineers. Two forms of agreement are currently offered:

■ *Service Level Agreement*, where ABB performs the actual preventive (condition-based) maintenance on a regular basis, with a minimum interval

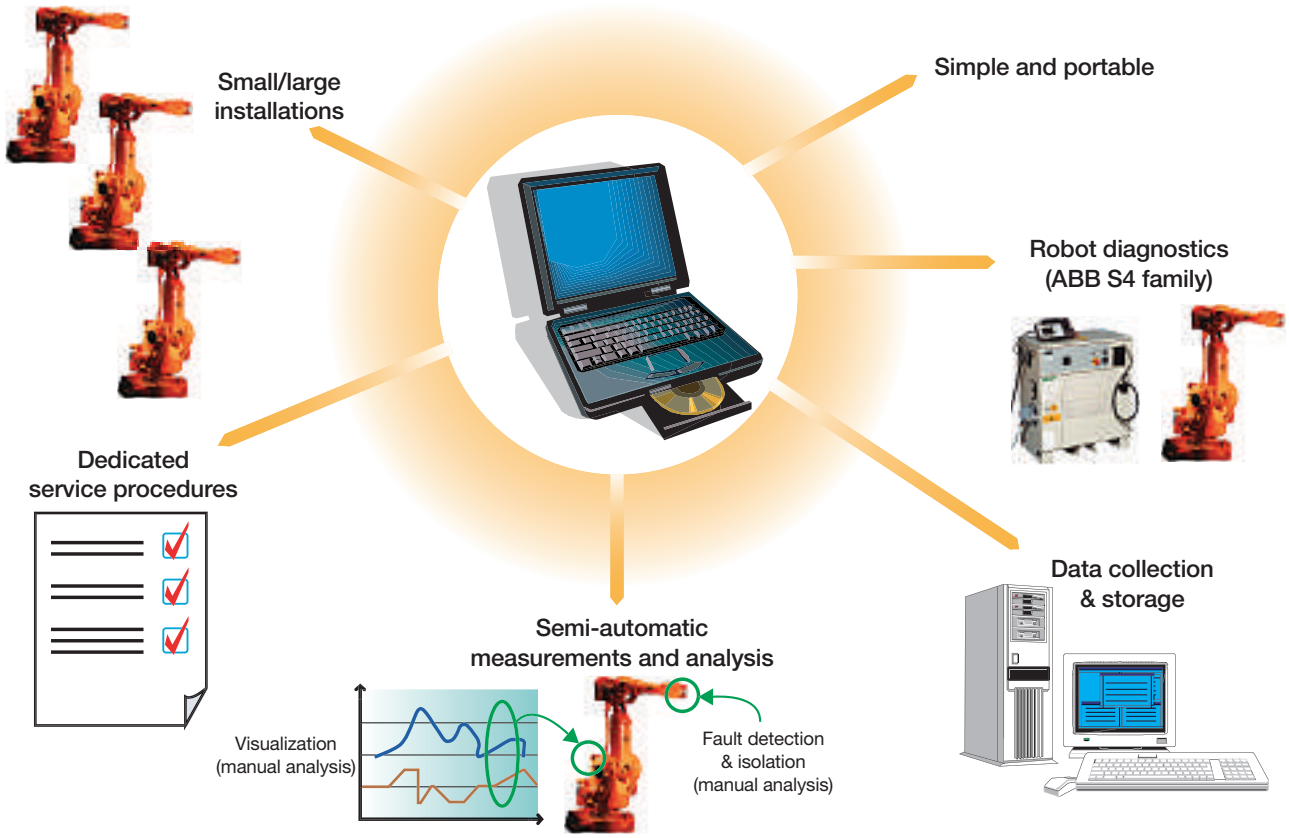
Robot hardware and software

All robot manipulators equipped with the S4 Industrial Robot System RW 2.0 to 2.1:
Items required to run OptimizeIT Robot Condition Monitoring:
■ RAP communication
■ 16-MB memory board

All robot manipulators equipped with S4C – S4P Industrial Robot System RW 3.0 to 3.2:
Items required to run OptimizeIT Robot Condition Monitoring:
■ Factory Ware Interface
■ 16-MB memory board
■ Network board (option)

Available from mid-2002:
All robot manipulators equipped with S4C+ – S4P+ controllers:
Items required to run OptimizeIT Robot Condition Monitoring:
■ Factory Ware Interface

Overview of the main Optimize^{IT} Robot Condition Monitoring functions



between maintenance of one year. This agreement may also include other services, such as ABB S4Anywhere® remote guidance, S4Remote®, or DDB WebWare™ for remote helpdesk support and diagnosis.

■ *Annual Check-up Agreement*, where the customer is responsible for the daily and preventive maintenance and ABB performs a condition check-up at least once a year to ensure and confirm the user's maintenance routines.

Main functions

Optimize^{IT} Robot Condition Monitoring supports systematic working procedures, guiding the engineer as he runs through scheduled maintenance routines. It supports faster trouble-shooting, getting quickly to the root cause of a failure. The tool automatically measures critical variables, which it stores to provide engineers with performance data and a knowledge database to support data analysis. With these features, users can identify, track and respond quickly to problems occurring during production. A full maintenance status report is generated with recommendations for optimizing the process or ensuring undisturbed production.

Optimize^{IT} Robot Condition Monitoring provides a flexible framework for service- and maintenance-related activities. Support is provided in the following main areas:

■ *Service procedures:* For all types of robot and controller versions.

■ *Measurement & Diagnostics Components (MDCs) toolbox:* A collection of MDCs that can be started from the user interface to support service or maintenance. Test results generated by an MDC can be added to the service or maintenance report and also be stored for future references.

■ *Documentation index:* Helps users find documentation needed for certain tasks.

■ *Analysis and support functions:* Packaged in MDCs (see Table opposite).

■ *Knowledge Database:* Connected to the user interface and MDS system. Using this data, robot footprints or error sequences can be compared with stored knowledge acquired by field engineers.

Other features are:
■ *Data collection:* Log messages, process statistics, reliability metrics, etc
■ *Data analysis:* Error detection and isolation, error and cause identification
■ Standard, online system
■ *Reporting:* Standardized maintenance guide for preventive and corrective maintenance, knowledge base building, integrated measurements
■ Standard and customized checklists for commissioning, maintenance and service
■ Capable of expansion with customized and modularized MDCs

Visualization and reporting

During commissioning or when carrying out maintenance or service work, the user can pull up a checklist specially tailored to his robot model and application. The integrated measurements can be either selected and initiated manually or performed automatically. Storage and diagnosis of the data are automatic. All measurements and critical variables can be displayed for analysis, eg as speed and torque graphs for each robot axis, together with the results of the robot self-tests.

Maintenance and service reports listing critical variables, torque profiles and diagnosed problems are generated automatically, and can be stored or retrieved for reference.

Feedback from the field

By definition, an improvement in the overall effectiveness of equipment will lead to more efficient production. A cost-effective approach is to focus on how assets are being utilized at the moment, and this is what Optimize^{IT} Robot Condition Monitoring does: For example, it answers questions like: Why do breakdowns occur? Why aren't failures prevented by the present maintenance routines? Is my robot operating at its optimal speed? What actions should I take during the next scheduled stop?

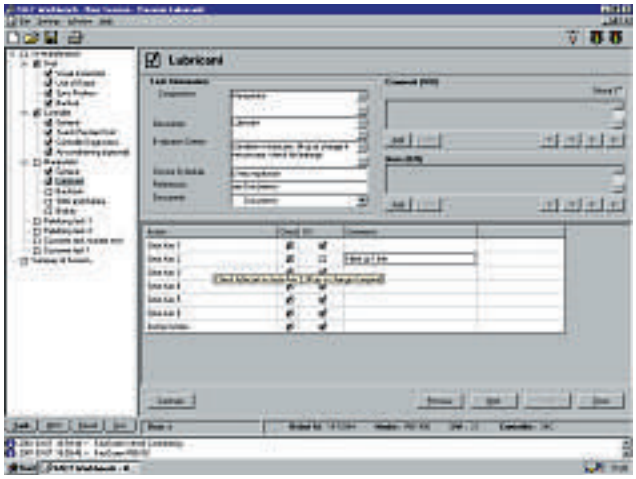
Two typical problems on a produc-

System architecture versus functionality

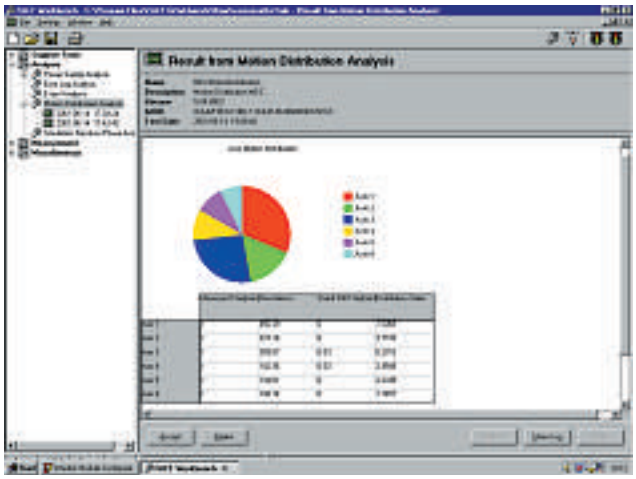
Optimize^{IT} Robot Condition Monitoring provides performance data as well as a knowledge database to support analysis. Data can be exported to other systems, such as the ABB knowledge database, or used to generate detailed maintenance reports.

Subsystem	Functionality	Description
OptimizeIT Robot Condition Monitoring tool	Data acquisition	Acquires raw data from robot
FBB Server	Data collection Data pre-processing	Collects data from FBB. MDCs can use FBB Server via an automation interface (Microsoft COM) to retrieve data from FBB.
MDS (collection of MDCs)	Analysis/diagnosis Monitoring support tools	Requests data from FBB Server or directly via InterLink. Performs various types of analysis or processing of data. Also provides a variety of support functions to facilitate common tasks performed by service engineer.
FWB	Service procedures Adaptive doc. links Visualization, result and knowledge database storage	Front-end of system. Basic features: electronic checklists and adaptive documentation links, and visualization of measurement and diagnostics results. Also provides a browser that allows easy navigation, database access for storage of robot configuration and maintenance data, and a report generator.

Screenshot of a maintenance routine with dedicated robot maintenance check-sheets



Screenshot showing the motion distribution of each single robot axis during a production cycle.



tion line are looked at in the following to show how this tool handles preventive and predictive maintenance.

Preventive maintenance

If equipment fails shortly after preventive maintenance has been carried out, the maintenance engineer will inevitably wonder whether the work was done properly. More often than not, he has to rely on his interpretation of the data, and this will likely involve some guesswork.

Plant managers need updated information on the condition of equipment in their plants to be able to estimate remaining lifetime. Continuous condition monitoring lets maintenance managers schedule preventive action and avoid costly robot downtime.

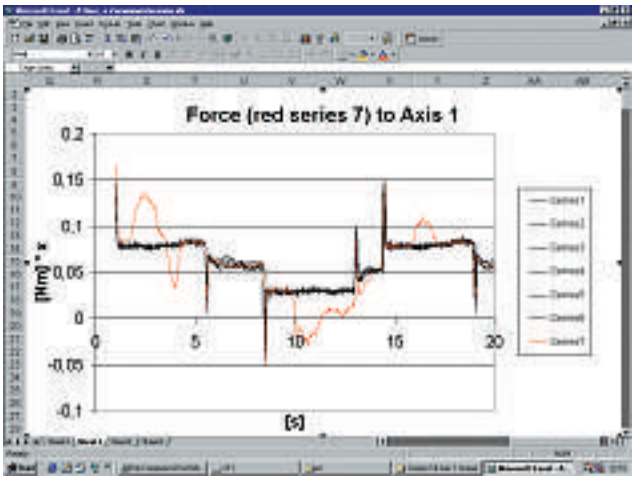
But what if he guesses wrong? Even following the most detailed maintenance procedures will not help then. The result will depend on a variety of factors, for example his experience and skills, or the tools at his disposal.

Optimize^{IT} Robot Condition Monitoring solves this problem by giving the maintenance engineer no second option: He has to follow the procedures precisely, and at the same time receives all the support he needs in the form of digital documents, checklists and measurement data.

Predictive maintenance

The value of predictive maintenance is shown by the following case: An industrial robot's torque reading had been recorded and stored during commissioning, but during the annual check-up six months later one of the Optimize^{IT} graphs showed a large deviation from the previous reading on one of the axes. The robot, which was assigned the task of off-loading and

Screenshot showing the actual measurement of speed and torque of robot axis 1, with clear deviations indicating a possible problem



positioning parts at the end of a line in a clean-room environment, was critical to the production process. Failure of the robot would disturb the entire production process and have a negative effect on productivity.

The cause of the deviation could not be determined as the production logs showed nothing unusual. It was likely, however, that there had been some kind of collision as the torque readings for axis 1 showed higher than usual values.

The powerful robot drive system kept things running normally, but either a motor, a gear or a bearing somewhere had been damaged .

The consequence of this was that the check-up interval was shortened to one month, extra inspection intervals were added, and an inspection/repair plan was scheduled for the next planned stop. Without the Optimize^{IT} Robot Condition Monitoring reading, no-one would have known about this potentially very costly failure.

Productivity improvement

The breadth of ABB's robot products and application experience gives our manufacturing customers the assurance that they can get on with the business of manufacturing while relying on us, as the world's premier robot supplier, to provide state-of-the-art and value-based productivity solutions.

ABB is stepping forward with service solutions that offer production plant managers all the experience, resources, high-tech tools, global organization and staying power they will need to address today's dynamic concerns.

Optimize^{IT} Robot Condition Monitoring

■ Addresses robot users' need to be able to monitor and optimize operations and assets.

■ Designed to easily and quickly identify deviations in robot performance. A knowledge database records the robot's maintenance history and detailed readings inform about impending trouble. This early warning capability averts unscheduled production shutdowns and allows manufacturers to maximize utilization of equipment and operate closer to its design limits, thus maximizing overall equipment effectiveness and profit.

■ Adds a new dimension to service support agreements. Whether for a single robot system, a welding or palletizing cell, a paint application plant, or a complete production line. This tool can considerably lengthen the life of the equipment.

■ Reports help management decide when a robot replacement is warranted as it is based on rigorous performance measurements.

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