Condition Monitoring Application

A Flexible and Cost Saving Condition Monitoring System for Wind Turbine Manufacturers

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Allen-Bradley • Rockwell Software

Rockwell Automation

Application Requirements

A wind farm is usually operated from a site control room with SCADA system access to each turbine. There are local HMI displays and data historians at each wind farm. Specific sets of data are also archived in a central database at the OEM's/End User's site.

Because uptime is so critical, manufacturers of wind turbines offer their units with a condition monitoring system.

A typical condition monitoring system may include a 10 – 20 channel vibration monitoring system that monitors vibration on the main drive shaft bearings, on each gearbox and on each generator bearing. The system may also include an oil-particle counter for the gearbox.

The vibration monitoring system should seamlessly integrate primary data into the site's existing SCADA systems and provide detailed data including spectrum analysis for trending and longer term predictive maintenance purposes. The system must work properly with SQL database servers and be easily expanded to match an expanding installed base of wind turbines.

Rockwell Automation's Approach

Executive Summary

The key attributes of the presented approach are:

- The MachineDynamix multiplexing concept minimizes required hardware and increases functionality.
- The XM-121 Low Frequency vibration monitor includes complete set of vibration measurement functions, including spectrum analysis, for two accelerometers plus tachometer.
- CompactLogix™ multiplexes pairs of accelerometers into XM-121 plus reconfigures XM-121 to help optain optimal measurement sets.
- CompactLogix executes custom rule sets to automatically identify potential mechanical problems.
- CompactLogix can provide data buffering to help ensure data is not lost if Ethernet communications to the control room is temporarily lost.
- CompactLogix provides direct interface to historian and HMI displays at wind farm control room with automated alarms and problem identification displays. Local operators get immediate and continuous feedback on turbine condition.
- An automatic connection is established to the powerful Emonitor® vibration data analysis software package running on a central database server. This is a state of the art vibration analyst's tool for tracking the condition of all of the user's installed machines.
- Additional monitoring or control functionality can easily be added at any time.
- The total system easily expands to accommodate growth in wind turbine installations.

Basic Concept

The MachineDynamix™ system combines standard XM Series vibration monitoring systems with the CompactLogix automation controller to provide an automated surveillance-mode vibration monitoring and data analysis system that will meet most requirements.

The Allen-Bradley® XM® Series is a high-speed, real-time vibration monitoring system that provides real-time and predictive maintenance information. The XM Series is based on a modular, DIN-rail mounted design.
The XM-121 Low Frequency module, is a self-contained 2-channel vibration analysis module that includes spectrum analysis.

The Allen-Bradley Logix family of automation controller products is designed to support a wide range of automation processes including sequential control, SCADA, process, motion, and complete automation systems.

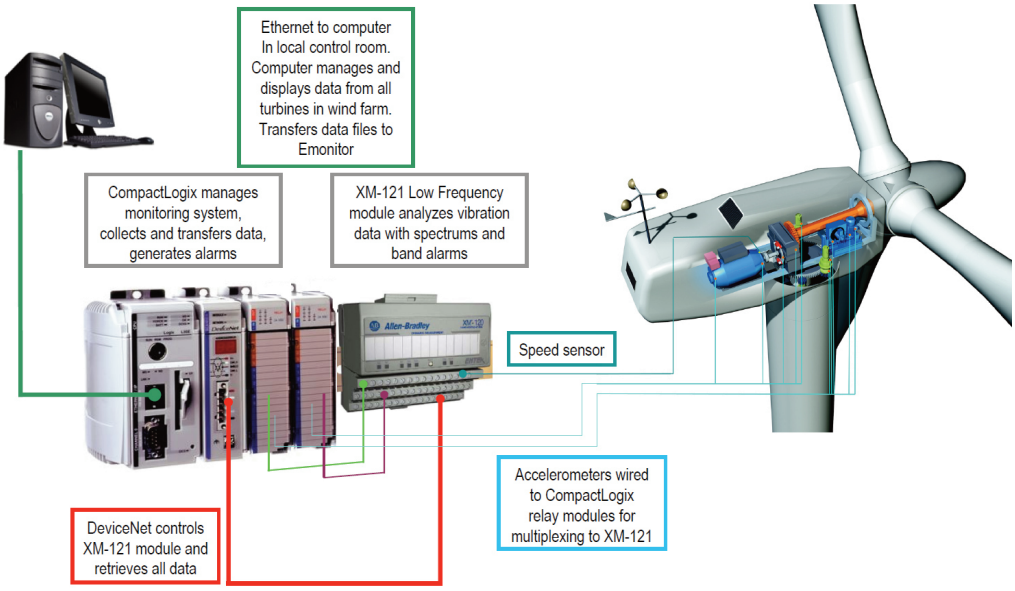


Figure 1. MachineDynamix: Basic structure

In a MachineDynamix configuration the CompactLogix controller will sequentially multiplex pairs of accelerometers into a single 2-channel XM-121 Low Frequency vibration monitoring and analysis module. Simultaneously, the CompactLogix downloads the optimal XM-121 configuration parameters via DeviceNet for the specific pair of accelerometers connected to the module. The XM-121 generates a complete vibration analysis including the spectrum analysis with frequency band alarms. This data is retrieved by the CompactLogix via DeviceNet and the process repeats for the next set of sensors. Depending on the XM 121 data analysis specifications that is customer specific, a complete set of data from all ten accelerometers can be collected every 2-5 minutes.

As the data is collected, the CompactLogix applies a set of data analysis rules that corresponds to the actual application to identify specific mechanical problems in the drive train. The CompactLogix requires an Ethernet connection to the control room at the wind farm. Through this Ethernet connection, the HMI and process historian can access all of the single-value measurement data generated by the MachineDynamix system, all of the mechanical problem analysis data, and all of the alarms from the XM-121 module.

A computer located in the wind farm control room runs the XM-Emonitor Gateway software on a scheduled basis. It is responsible to retrieve a full set of data including spectrums and transfer it to a master monitoring computer to be loaded into the central Emonitor vibration data analysis software database on a main server.

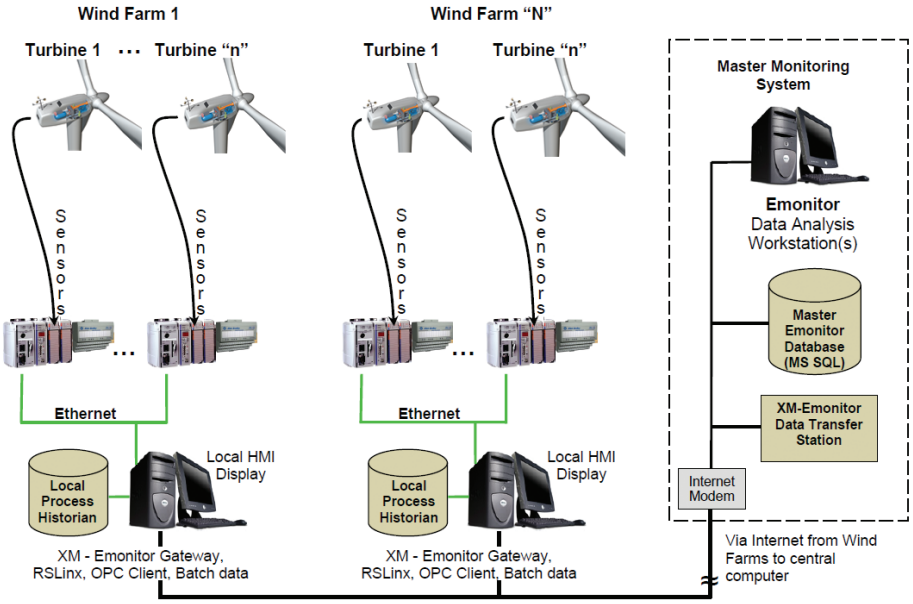


Figure 2. Global communication concept

Vibration Monitoring System

A XM-121 Low Frequency 2-channel vibration monitoring module accepts inputs from two accelerometers and one speed detector. The module will continuously make the following single-value measurements for the connected accelerometers:

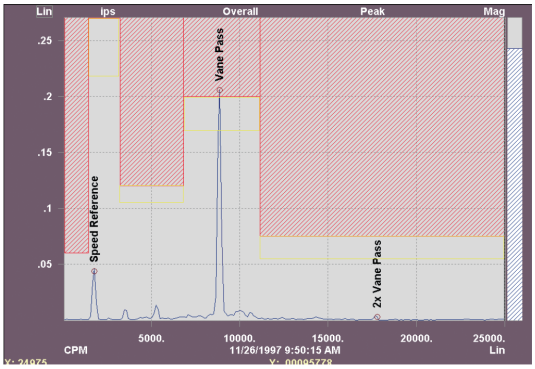
Per Accelerometer

- Overall Vibration
- RMS, Peak, Peak-to-Peak
- 1x, 2x, 3x Magnitude
- 1x, 2x Phase
- Sum Harmonic Energy
- Not 1x Magnitude
- (4) Programmable Frequency Band Alarms

Per XM-121 Module

- Speed
- Acceleration (RPM/Min)
- Max Speed

In response to a specific request from the control system, the XM-121 module will also provide time waveforms and up to 800 line spectrums in addition to the single value data. Spectrum measurements and the four programmable frequency band alarms can be specified in frequency or orders (multiples of running speed). Orders-based measurements are generally used on variable speed applications.



The XM-121 includes 16 programmable two-level alarm outputs that can be set to track and alarm on any of the measured single-value data. The frequency band alarms can be programmed to bracket specific bearing and gear frequencies to track possible failure modes on a continuous basis.

The XM-121 measurement definitions for the two channels are completely independent from one another which allow optimized operation for each sensor. The module settings can be easily changed through the integral DeviceNet communications network on the XM-121. All of the measured data, both single-value and spectrum and time waveform, as well at alarm outputs can also be accessed through this DeviceNet connection.

MachineDynamix Controller

A CompactLogix system consisting of a Logix controller, DeviceNet scanner, and two relay cards provides the supervisory control for the MachineDynamix system. This system controls the multiplexing of the accelerometers, configuration of the XM 121 module, collection of the data, evaluates the data for machine problems, provides data buffering, and communicates the data to the rest of the system.

All accelerometers on the wind turbine are connected to sealed, gold contact signal relays on the two relay cards in the ControlLogix system. In a sequence controlled by the system program, the relays sequentially connect two accelerometers to the XM-121 Low Frequency module. At the same time, the specific measurement definitions required for those particular accelerometer locations to provide optimal vibration measurement results are downloaded to the XM-121 module via the DeviceNet communications link. When the XM-121 module has completed the required set of measurements, all of the required data is read from the module via the DeviceNet link and the process is repeated for the next pair of accelerometers.

If the user decides during the detailed analysis of his requirements that some of the accelerometers could benefit from having more than four frequency band alarms to detect problems or that it is necessary to take spectrums at more than one FMAX, this can easily be accommodated by loading a second set of measurement specifications into the XM-121 module and gathering a second set of data from a specific accelerometer. The MachineDynamix system provides this flexibility and power.

As part of a MachineDynamix system, a custom set of mechanical problem analysis rules can execute in CompactLogix on a continuous basis. The optimal set of rules for a user's specific machine characteristics has to be defined by the manufacturer. Rockwell Automation can support him in this task. These rules can combine all the measured data to automatically provide warnings of potential mechanical problems at the local operator control panel level. They are evaluated for every set of collected data for immediate feedback to the wind farm operators.

All of the "single value" measurements made by the XM-121 are collected in the CompactLogix processor and are available for trending and display at the local control room level via the Ethernet link that is standard on the 1769-L35E CompactLogix processor. Most process historians and HMI display software are capable of extracting data from this CompactLogix system. If needed, the processor can function as an OPC Server for this purpose. With this system all of the data that goes into the analysis rules can be continuously tracked and displayed at the local level. All of the alarms and warning of potential mechanical problems are immediately presented to the operators. The data can be stored in the user's local process data historian. This data can be updated as often as at approximately 2 minute intervals.

If the Ethernet connection is lost between a wind turbine and the wind farm control room, the CompactLogix processor in the MachineDynamix system can retain all the time-stamped 2-minute interval single value data for several hours. However, most historians and HMI systems are based on currently polled data and are not capable of importing the accumulated data. If the user's systems are capable of retrieving this accumulated data after the communications are reestablished, the data will be available.

At each wind farm, we need a computer running RSLinx and OPC Client software along with the XM-Emonitor Gateway software. Emonitor is Rockwell Automation's primary vibration analysis tool that the user or OEM's qualified analysts would use for detailed evaluation of the vibration data. The primary Emonitor database will run on a central database server. The XM-Emonitor Gateway will be used to extract the specific data from the MachineDynamix system that the user wishs to store permanently in the Emonitor database on a schedule that he can define. Generally this includes some of the overall vibration data, the frequency spectrum, and possibly the time waveform. This is completely separate from the single-value data that is always available at the local control room level.

Vibration Data Analysis System

The Emonitor Factory software combined with the MachineDynamix system will provide the capabilities that are required. For many years Emonitor has been accepted as the leading vibration analysis software package available in the market.

Emonitor Factory is a fully Windows® compliant, powerful data analysis and archive tool that utilizes an Oracle or MS SQL database server to manage and analyze data from large multi-site systems. The primary database can be located at HQ's and data analysis stations can be in the control room or at another location. Emonitor Factory comes with two simultaneous user licenses and additional seats can be purchased to scale the installation to customer specific needs.

One or more Emonitor Data Transfer Stations (a PC with our DTS software loaded) must be located at the user's main server location. The XM-Emonitor Gateway at each wind farm will send scheduled data files back to the DTS for each pair of sensors that are analyzed through the XM-121 module. As the files arrive, the DTS will import the data into the Emonitor database on the server. It is possible to configure the Emonitor Factory database so that all data is stored in a single database or it can be segmented so that each wind farm is a separate database on the database server. Emonitor Factory can easily work with either a single or multiple databases.

Emonitor Factory software can be loaded to multiple machines located anywhere across the user's network, but only two users can simultaneously access the database (additional seat licenses are available). For remote data analysis with read-only access to the database, there is an optional Emonitor Web Client available. With the web client installed, remote users can access the database using a standard Internet Explorer web browser. This is an excellent tool for use at the various wind farms – data visibility is provided throughout the enterprise in read-only access.

In this kind of application, there normally is a large number of identical machines being monitored. Emonitor Factory has the ability to perform statistical analysis against the spectrums for a given transducer location on a large number of machines to develop very tight spectrum band alarms that continuously update based on the measured data. In addition to the alarming just on a vibration measurement, Emonitor allows to add up to four process points per statistical alarm which allows the proper alarm level to be achieved for a specific process or function. This allows you to optimize the data analysis processes.

It is also possible to set up Emonitor Factory to automatically evaluate each data download against the established alarm levels and immediately issue an email alarm notification of any parameter that is in alarm.

This helps minimize the necessity of continually logging-on to check for alarms.

Another option available for Emonitor Factory is the Intelligent Advisory Decision Module. The IA Decision Module provides the ability to define many simple or complex logic rules that Emonitor can use to automatically evaluate current data and return diagnoses when specific logic conditions are met. This tool will be most effective after a good set of baseline data with statistical spectrum alarms has been developed to provide a high quality starting point. Once it is set up, it will be able to provide most of the problem analysis in a fully automated form with email advisories automatically generated. We suggest that this option be added to the system after 6-12 months of data has been collected.

Summary

The MachineDynamix approach offers the clear advantage of an easy development of the system. If the user wanted to expand the number of sensors monitored or add more system control or SCADA capabilities to the CompactLogix processor used in the MachineDynamix system, it is a very simple and straight forward task. It would be possible to fully integrate a TCU control functionality into the same processor as the MachineDynamix system. It may necessitate upgrading to ControlLogix to handle everything, but all the programs are directly transferable.

As an example of the expansion capability, it would be relatively easy to integrate an oil particle sensor into the MachineDynamix system by the simple addition of an input card to the CompactLogix.

Another example would be adding more accelerometers. Assume it would be shown that better results would be reached if two accelerometers were used on each gear box. Increasing from 10 to 14 accelerometers on the installation adds absolutely nothing to the MachineDynamix system. Just wire the added accelerometers to the multiplexing relay modules, change the program to recognize the added sensors, and it is done.

This approach offers excellent flexibility compared to any other potential solution.

www.rockwellautomation.com

Power, Control and Information Solutions Headquarters

Americas: Rockwell Automation, 1201 South Second Street, Milwaukee, WI 53204 USA, Tel: (1) 414.382.2000, Fax: (1) 414.382.4444
Europe/Middle East/Africa: Rockwell Automation, Vorstlaan/Boulevard du Souverain 36, 1170 Brussels, Belgium, Tel: (32) 2 663 0600, Fax: (32) 2 663 0640
Asia Pacific: Rockwell Automation, Level 14, Core F, Cyberport 3, 100 Cyberport Road, Hong Kong, Tel: (852) 2887 4788, Fax: (852) 2508 1846

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