DEVELOPMENT OF AN ON-LINE SYSTEM FOR VIBRATION MEASUREMENT AND TRACING

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Abstract

Vibration is a significant issue in relation to accelerator commissioning. The utility system has many mechanical parts and induces severe vibrations. For the purpose of tracing the source of vibrations and preventing failure of the facility, an on-line system for vibration measurement and tracing has been developed, adopting a programmable automation controller with a FPGA function to conduct data acquisition with its algorithms. This system including specific analysis of time and frequency domains has been integrated into the previous system for monitoring and archiving. A convenient interface provides on-line analysis and traces the source of vibration via a network, anywhere and anytime.

INTRODUCTION

Much evidence has indicated that an accelerator is sensitive to vibration signals [1][2]. The utility facility has many mechanical rotary parts or moving parts, such as pumps, fans, chillers etc. Some vibration phenomena exert a significant influence on beam stability. Vibration is suspected to propagate along paths from water piping, ground etc. To clarify further, an on-line measurement of vibration is required. In general, a vibration signal can be detected with dedicated instruments, such as a dynamic signal analyser, or simple portable vibration measurement devices, but the vibration information must be stored and analyzed after completion of all measurements. This process might produce a loss of on-line information and misunderstanding of the phenomena. A commercial system to measure vibration includes many unnecessary functions that increase the cost. These conditions encourage building a comprehensive system to measure vibration for a utility facility.

To provide an intuitive, integrated, inexpensive and multi-channel system to measure vibration in real time, we propose a structure integrated with an existing utility facility monitor and control system (FMCS). This system adopts a programmable automation controller (PAC) of high performance with a field-programmable gate array (FPGA) to act as distributed data acquisition stations to collect all vibration signals. The signals are transmitted to the main server for data analysis and limit settings at the same time via Ethernet. The client software can access the entire vibration signal anytime and anywhere.

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On-line machine monitoring and protection constitutes important information about a utility facility because it provides the principal information about the status of a machine. Monitoring these data with vibration analysis allows us to predict the failure early and to schedule appropriate maintenance. In general, this information can provide three months of lead time before an actual date of failure. It is helpful to prevent unscheduled outages, to optimize machine performance, and to decrease repair time and maintenance costs.

DATA ACQUISITION OF VIBRATION SIGNAL

Because the processing of acquired vibration data and the associated algorithms are complicated, an ability to combine the advanced software capabilities of a standard computer with the reliability of a programmable logic controller (PLC) is required. The controller must have increased loop rates, advanced control algorithms, additional analogue capabilities, and improved integration with the enterprise network to meet the requirement of vibration measurement. The National Instrument (NI) PAC with real-time controllers and FPGA are selected to undertake all distributed data acquisition. This FPGA function enables us to incorporate extremely time-critical functions into the hardware, which uses the ability of rapid data acquisition to accept packets of data with a sampling rate 1 – 2 kHz, and then to use a DMA and interrupt function to transfer data into the real-time controller RAM without delay. The real-time controller proceeds with a floating-point FFT algorithm with an adequate window length and transmits the native time waveform to Ethernet [3]. The main server located on the same network can accesses these data via Ethernet to conduct rapid data storage. The flow of vibration data is shown in Figure 1.

To decrease the duration of development of design and to maintain a data-file format, a TDM streaming-data model defined by National Instruments has been adopted. This TDM streaming is designed to write real-time data quickly and efficiently to a disk, instead of writing data in a binary format with no predefined framework. The TDM streaming data offers a hierarchy at three levels for associated descriptive information and unlimited data types. These TDM streaming data also have an auto-generated binary index file to provide consolidated information on all attributes and pointers in the bulk data file, which makes it search-ready.

Currently, the vibration data are also written into three levels: the first is a date stamp, the second level is a time stamp and the third comprises data clusters of unlimited length as a time waveform, as shown in Figure 2. All data for vibration signals can be saved periodically.

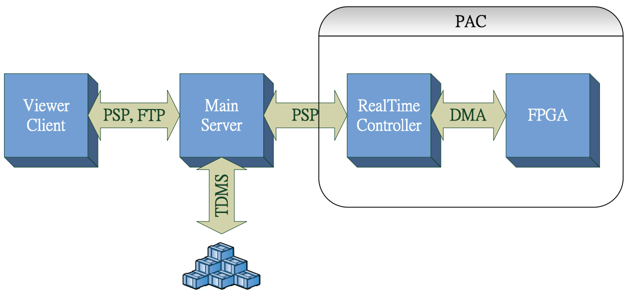

Figure 1: Data flow structure.

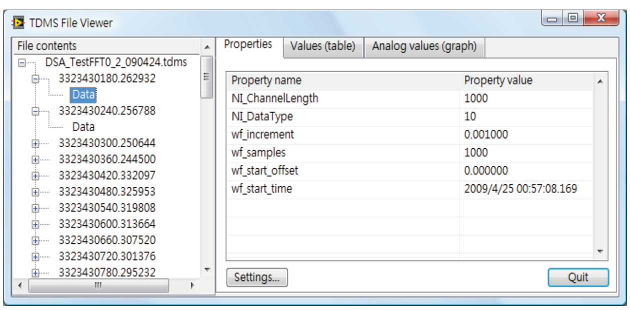

Figure 2: TDM streaming file format.

MECHANISM OF COMMUNICATION OF VIBRATION SIGNALS

Our system of vibration measurement adopts the previously developed native network architecture. To attain the data transparency of hybrid network systems comprehensively, a protocol 'publish and subscribe' (PSP) developed by National Instruments and a FTP protocol are adopted; the former takes charge of on-line data, and the latter treats off-line data communication. The PSP combines the TCP/IP and UDP merits to provide efficient data communication. The protocol uses a smaller network bandwidth than a TCP/IP and has the stateless and connection-less aspects of a UDP. This protocol allows us to define a time and spectrum waveform with no limit for the data type and length. The cluster data format has been defined to transmit data among computers and PAC.

The PSP also supports a buffer mechanism to ensure that all updated values reach the subscribers. While the main server is busy for another program thread, the dedicated buffer caches the updated value until the buffer overflows. To assure data completion, this mechanism prevents loss of time waveforms. The time waveform requires a high-throughput network and has no need to ensure that each datum reaches exactly because the vibration signal almost invariably continues to appear in the utility facility for a few seconds.

In general, the controller levels are hardware layers with distributed PAC, which undertake vibration measurement as shown in Figure 3. When the PAC are ready to receive data, the first layer of the data exchange engine, also called a shared-variable engine, becomes boosted. This level always has a dedicated controller network to transfer the time and spectrum waveform. The main server located on the same network collects and saves the raw data via a shared-variable engine. The main server also acts as the gateway of the shared-variable engine and isolates the network from the control level and data-service level. A shared-variable engine located on the second layer with a bi-directional mechanism of connecting to the previous shared-variable engine is created to diminish network interference that affects PAC performance. Thereby the PAC can maintain data acquisition without interruption. Finally, the convenient human-machine interface (HMI) software with on-line and off-line display located on the data-service level network proceeds with analysis of the power spectrum from the time waveform. The software can access all PAC to trace the suspected path of propagation from the source of vibration.

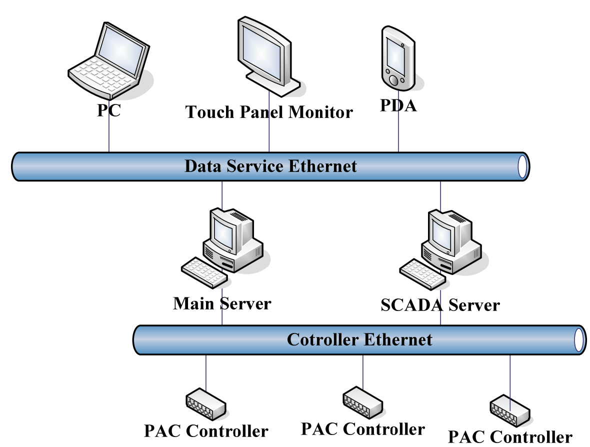

Figure 3: Network structure of the vibration measurement system.

ON-LINE AND OFF-LINE DISPLAY OF THE POWER SPECTRUM

Previously, an 'Archive Viewer' was developed with a series of on-line data-view functions, including table view, graphic view, web view, trend view, and dynamic signal analysis (DSA) view. The DSA view has been upgraded to possess an on-line trace function and an off-line history view. The on-line trace function accesses the streaming data to undertake analysis of a power spectrum. The built-in algorithm for the power spectrum can calculate on-line the time waveform data on the client side. The function also provides some necessary parameters to be tuned, including window type, scaling etc. For the purpose of trace and comparison, the graphic power spectrum can be intuitively dragged and dropped to move each signal to the appropriate group locations as shown in Figure 4. Analysis of the relations among multi-channel and on-line vibration data then occurs within 1 s. For example, if the chillers become sources of vibration on the spot, the neighbouring ground and remote piping can be monitored dynamically at the same time. These reference signals show on the display simultaneously, which can enable tracing all vibration signals and clarifying the paths of propagation.

The main server not only transmits the time waveform data to the client software but also acts as a recorder with the TDM streaming file format. According to various request date and signal, the client software can access these data via the FTP protocol as shown in Figure 5. It is thus helpful to observe fully the trend as a historical reference of machine commission conditions. The function can be used to diagnose the failure status of the utility facility and to provide a prediction alert for routine maintenance.

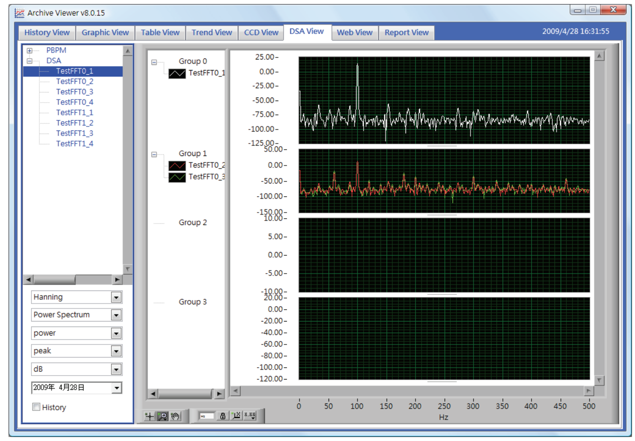

Figure 4: On-line power spectrum display.

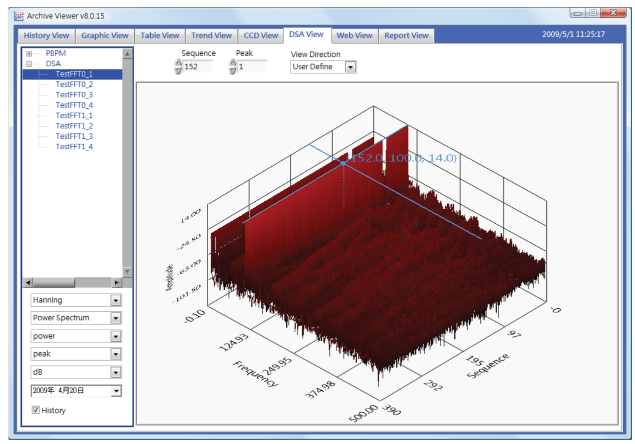

Figure 5: Waterfall display of a historical power spectrum.

CONCLUSION

For a system of vibration measurement and tracing, our effort is devoted to develop an on-line measurement structure that differs from commercial instruments for vibration measurement. The system adopts PAC with embedded FPGA chips to acquire the distributed vibration signal. The PSP protocol is used also to transmit on-line data to the main server, and the client software can access all distributed vibration signals and proceed with an on-line analysis of the power spectrum.

The software currently provides an on-line similarity comparison and an off-line historical analysis. Development of the system continues toward tracing specific frequencies and creating an expert system of a vibration database. The system will be extended to treat all dynamic signal analysis, such as power quality etc.

ACKNOWLEDGEMENT

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