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Implementation of Spectrum Analysis System for Vibration Monitoring

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Abstract

Factory monitoring systems are gaining importance in wide areas of industry. Especially, there have been many efforts in implementation of vibration measurement and analysis for monitoring the status of rotating machines. In this paper, a digital signal processor (DSP) based monitoring system dedicated to the vibration monitoring and analysis on rotating machines is discussed. Vibration signals are acquired and processed for the continuous monitoring of the machine status. Time domain signals and fast Fourier transform (FFT) are used for vibration analysis. All of the signal processing procedures are done in the DSP to reduce the production and maintenance cost. The developed system could also provide remote and mobile monitoring capabilities to operator via internet connection. This paper describes the overview of the functional blocks of the implemented system. Test results based on signals from small-size single phase motors are discussed for monitoring and defect diagnosis of the machine status.

Keywords: *Signal analysis, Spectrum, FFT, Vibration monitoring, Microcontroller.*

1. Introduction

In many areas of industry, monitoring the operation of machines in factories is becoming an essential part of requirement. The analysis and monitoring help the manufacturers to detect various types of faults and to implement the predictive maintenance system to reduce the production expense and to extend the life span of the machines. According to the characteristics of the manufacturing processes, the vibration is one of the most important sensing data to be monitored and analysed because it is directly related with the fault on rotating machines [1]. The analysis of the vibration signal is very effective in fault detection and diagnosis, since each defect in machine produces particular types of signals with distinctive spectral characteristics in the frequency domain that can be measured and compared with reference data to identify the defect parts.

Both time domain and frequency domain approach are the most popular techniques which are used for vibration analysis [1-3]. The time-domain information provides an insight on the physical nature of the vibrations. However, with the time-domain information, it is very hard to analyse the multi-tone vibration signals. On the other hand, frequency information, including amplitude and phase spectrum, is more helpful

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for the vibration analysis. The frequency analysis of the vibration information followed by further processing of the calculated spectrum allows us to obtain precise diagnosis information. With the development of the microprocessor technology and digital signal processing techniques, especially fast Fourier transformation, the frequency spectrum can be obtained for real time monitoring [4].

In this work, we develop a DSP based vibration monitoring system which analyses the vibration signal both in time and frequency domain in real time and transfer this information to various types of devices via internet connection. The developed system has multiple input channels which take both voltage and current signal from sensors. This system can provide a real time online monitoring tool for manufacturers to enhance the level of efficiency of the factory operation.

2. System Model

As illustrated in figure 1 and figure 2, the developed monitoring system contains two main modules: a DSP module which collect and process the vibration signal and a control module used to store data and make a connection to the internet. The DSP module collects the analog signal from multiple vibration sensors which are attached to the monitored rotating machines. After that, the analog signals are processed by pre-processing circuit and digitalized by analog to digital converter (ADC). In the next step, filters are implemented to determine which frequency range should be monitored by the system. Then, the vibration signals are transformed into a frequency domain. As a final step, the information is moved to the control module for transmission through the network.

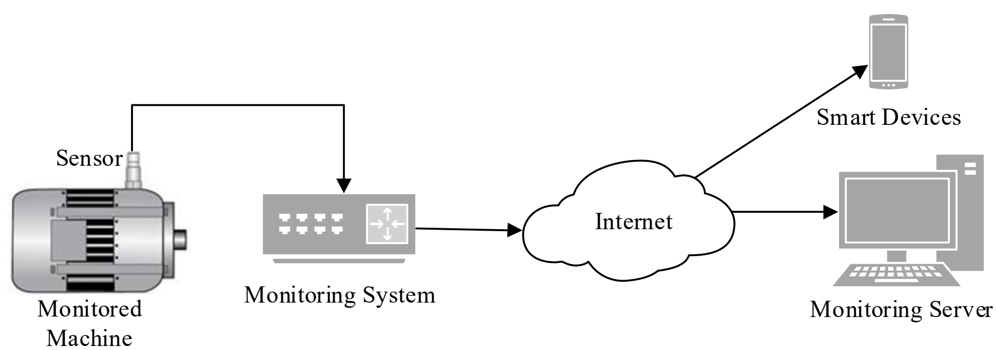

Figure 1. Overview of vibration monitoring system

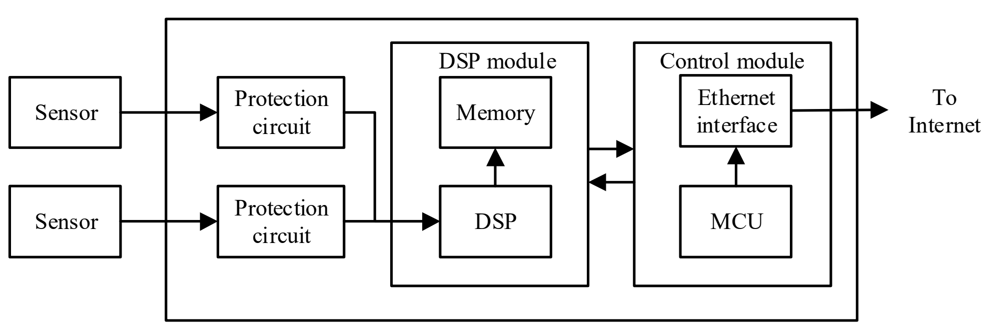

Figure 2. Block diagram of the developed system

The DSP module is mainly in charge of converting time domain vibration signal to digital data and implementing the fast Fourier transform algorithm to change the time domain information to the frequency domain one. After ADC, time domain data is stored in buffer memory with predefined size N (equal to FFT length). Time domain data is moved to the external memory block for the transfer to the control module. After the buffer memory fully filled with N samples, the DSP will carry out the Fourier transform to calculate the spectral information of the signal. The frequency domain data is moved to the external memory and waits for the transfer to the control module. After finishing up one cycle of FFT, the buffer is cleared and the ADC continues to take new incoming signal samples.

The dedicated software is developed to control the previously described monitoring system. It can be divided into three main procedures: signal collection and pre-processing, FFT, and interface with the control module. All of these procedures are done in the DSP in an effort to minimize the production and maintenance cost. In the DSP module, the ADC operates with voltage between 0 to 3.3V. The ADC output is unsigned integer ranging from 0 to 4096 with a 12-bit ADC. In some cases the DC removal circuit should be included before or after ADC depending on the design requirements [5, 6]. After that, the signal is passed through a digital filter to extract the desired frequency bands. The target bandwidth can be reconfigured if there is a request command from the server. The control register can store the configuration parameters for the filters, the FFT blocks and the ADC.

3. Experiment Results

As shown in figure 3 and figure 4, the system monitors the vibration signal acquired by accelerometer which is attached on the stator of a single phase motor. The time domain signal provides the input data to the FFT to infer the frequency spectrum of the vibration. Once the time and frequency domain data are fully filled in the buffer, the DSP module transfers these data to the control module. The control module updates the data to the server.

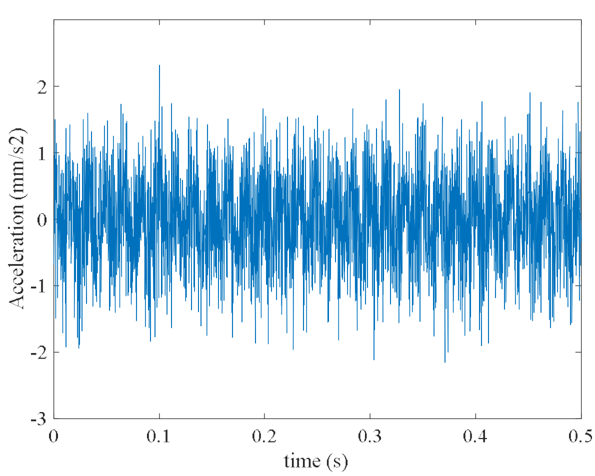

Figure 3. Vibration signal in time domain

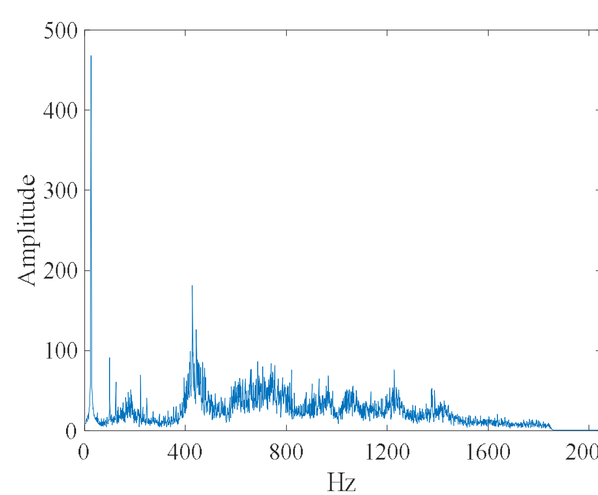

Figure 4. Frequency spectrum of vibration

4. Conclusion

This paper discusses the development of a DSP-based vibration monitoring and analysis system including the hardware and the software design. The developed system allows operators to carry out machine monitoring online, which helps to increase the safety and stability of factory operation environments. Vibration signals in both temporal and spectral domain can be used to analyse and detect the mechanical faults which could reduce the maintenance cost. The internet connectivity of the developed system can also provide remote and mobile monitoring capabilities which could also result in the reduction of operation expenses for the manufacturer.

Acknowledgements

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