An Expandable Vibration Monitoring Solution for the Complete Range of Manufacturing Businesses

Dr. R. E. Brown BEng (Hons) PhD MIEE

Research and Development, Monition Ltd. (International), Bonhay Lane, Worksop, Nottinghamshire, UK S80 3EH, Email: r.brown@monition.com, Tel+44(0) 1090 471000, Fax: +44(0) 1909 722208

ABSTRACT

This paper will describe a prototype vibration monitoring system, which has been designed to aid expansion from a simple manual data collector/analyser system, monitoring the state of vibration of a single machine, up to an automatic multi site monitoring system with remote indication of abnormal machine conditions. Controlled by a central supervisory computer the system is capable of collecting time domain vibration data from TCP/IP and wireless LAN networked data acquisition units, storing and analysing the data in the frequency domain and indicating abnormalities to local annunciators and via SMTP and GSM to remote system administrators.

It is envisaged that the development system therefore aids the viability of implementing vibration monitoring practices since it provides a method for staggered implementation of monitoring and subdivides the common maintenance benefit cost ratio judgment.

KEYWORDS

On-Line Vibration Monitoring, Global Monitoring, Automatic Monitoring

INTRODUCTION

It is proposed that the advantages of vibration monitoring are recognised by those engineers exposed to its theory and practices, yet to other engineers, higher management and their accounts who are about to, or have taken the first steps towards implementing vibration monitoring, the scope of available equipment and practices make the important outset decisions for future functionality of the proposed vibration monitoring system difficult. In most cases engineers will have to establish, control and justify the ratio of benefits to economics with the hope that the balance favours that of benefits. So how should knowledgeable maintenance engineers convince their peers to implement a vibration monitoring system when the peers may argue that the ratio is unity or economically inclined? One method could be to examine the performance of a small experimental system typically 100 points monitoring say, motors, gear boxes etc., incurring minimal initial economic outlay generally >5 K£ then to expand the system dependant on results. Yet, how can a large system, i.e. 'n' 1000 points, be implemented without losing valuable data and making initial equipment redundant?

Standard hand held vibration monitoring equipment such as the 21XX series meters distributed by 'CSI Emmerson Process Management', or the VB series meters of 'Commtest Instruments' when used in the overall operation scheme shown in Figure 1 have the inherent disadvantages described and further restricts future improvements to maintenance strategies by the inability to easily expand the system without increasing the reliance on human intervention. Figure 1, indicates the familiar flow of data in most vibration monitoring systems where the system relies on human action at three points.

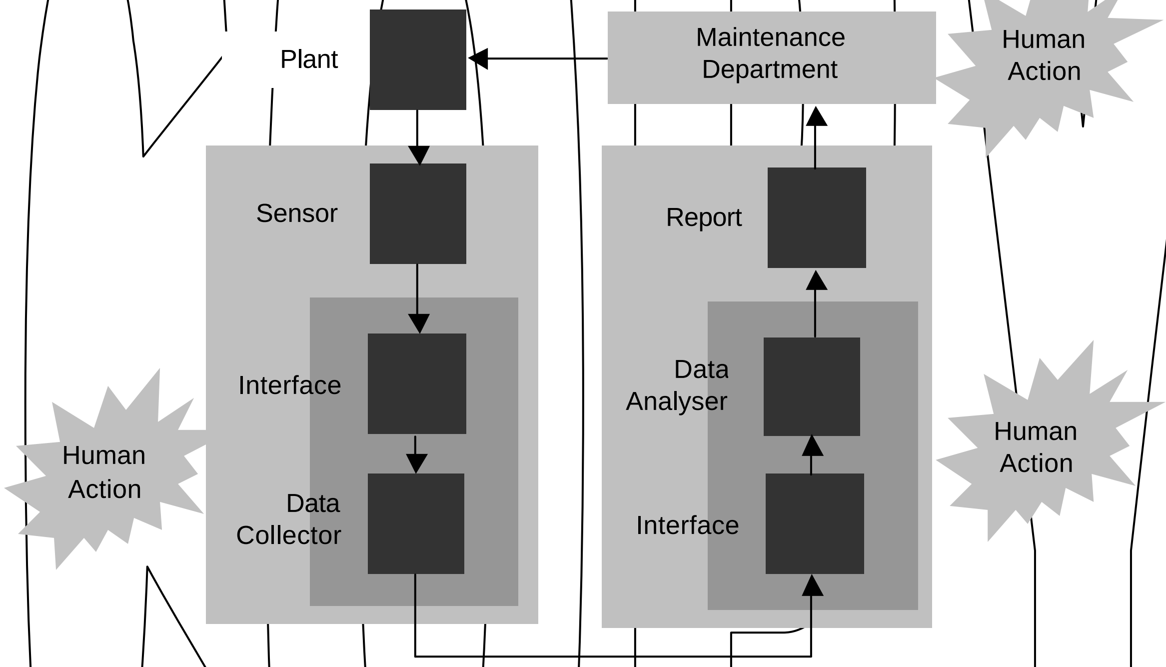

Figure 1 Diagram indicating the flow of data and the need and location of human intervention in most common vibration monitoring systems

In the scenario presented in Figure 1 the system first requires manual extraction and storage of data from the sensor via a data collector which is then further manually analysed resulting in some indication of the state of the plant which is then relayed to the local maintenance department for associated action which is, clearly a labour intensive and time consuming cycle.

A partial solution to the problem could be to combine the data collector and data analyser and provide word processing functionality together in a single unit, which could then be operated by a skilled engineer capable of producing a status report immediately on site. This system removes one of the human stages yet still has inherent demands on human time and effort if the system requires future expansion.

Yet another option could be to provide the unit with some intelligence by means of semi automatic analysis routines, therefore enabling plant maintenance operatives to use and judge to some degree the state of their own machines. In this case the frequency of data collection and quasi analysis can be increased providing better overall monitoring of the plant, whereas the requirement for specialist intervention can be decreased with an overall cost reducing result.

The attributes of this system were considered to be attractive and consequently directed the development of the system to be presented. Consequently, the initial objective of the project was to develop a hand held 'manual' vibration monitoring analyser, yet with an inherent vision to flexibility and expansion to a fully automatic personal computer based system with similar attributes first reported and developed by Kuo [1], Murray, Ratcliffe and Palmer [2] and Ramakrishna [3] and those currently distributed by Icon Research Ltd. [4] and Sensonics Ltd. [5].

Therefore, it is proposed to present the attributes of the individual stages of the expandable system, beginning with the description of the standard manual system and followed by the attributes of automatic waypoints and finally leading to the description of a fully automated system.

STANDARD VIBRATION MONITORING ANALYSER

For portability, the standard vibration monitoring analyser shown in the block diagram of Figure 2 was built and based around a universal laptop computer or a pen tablet computer referred to as a 'slab top', which utilised common operating systems and desktop publishing applications and therefore provided the user with powerful information technology tool. Additionally, system peripheral devices such as an auto gain amplifier (AGC) and analogue to digital converters (ADC) were attached to complete the overall system architecture.

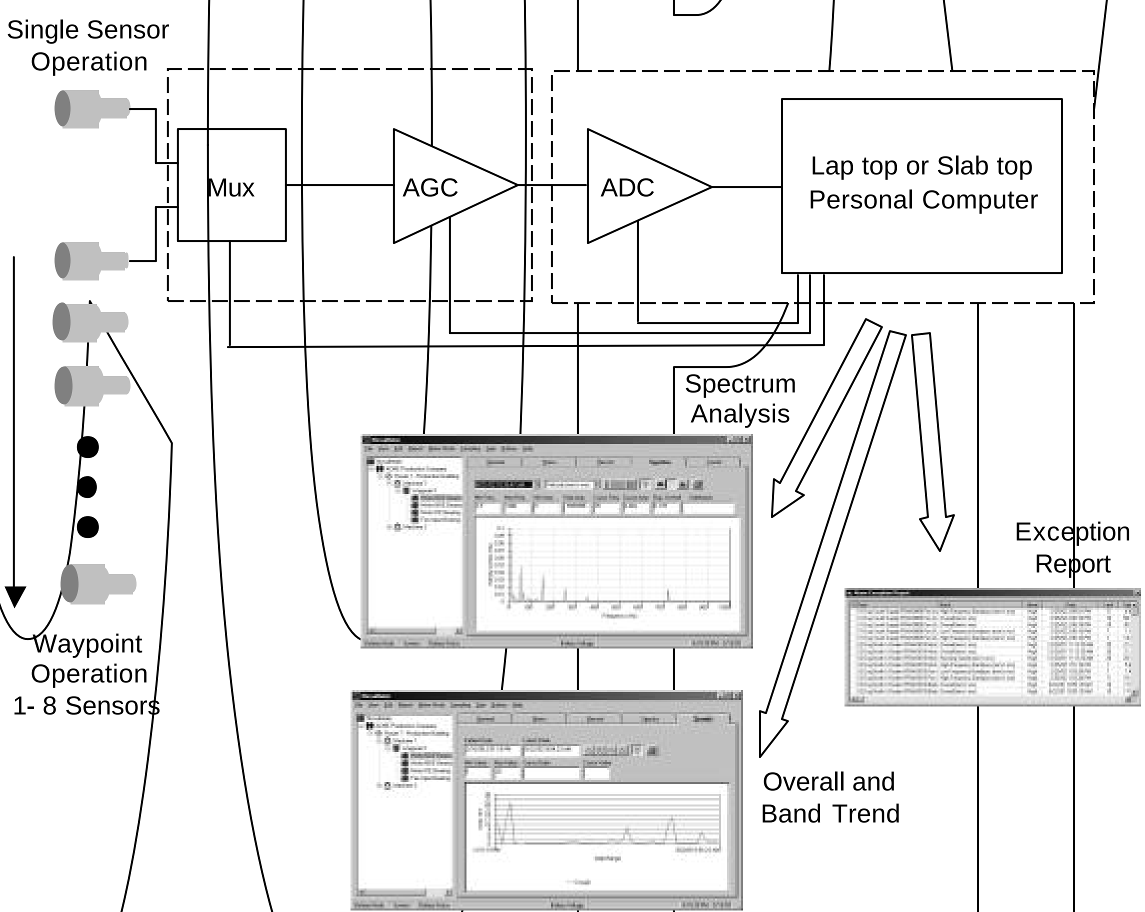

Figure 2 Architecture of Initial Vibration Monitoring Analyser.

Standard Analyser Hardware

A 16 bit, 200kS/s ADC was used, and was most often enclosed in the form of a 'credit card' type, PCMCIA card manufactured by Measurement Computing Corporation, Massachusetts, USA, which inserted directly into the computer. The card was capable of monitoring 16 single ended or 8 differential analogue inputs and also provided 8 controllable digital inputs and outputs. Now, one of the analogue input channels, differentially configured, was utilised to monitor the sensor signal and another analogue channel, also configured in the differential mode, was used to monitor the sensor power supply. The digital outputs were used to control, first, the application of power to the sensor via a suitable battery and then the AGC. Furthermore, the digital outputs were also used as select lines for multiplexing circuitry (Mux), which provided the system with the capability to monitor up to eight sensors sequentially when connected via a marshalling box referred to as a 'waypoint'. The AGC and multiplexer were assembled on a small printed circuit board and enclosed in a minor box with the sensor battery which were suitably attached to the rear of the computer.

Standard Analyser Software

The standard analyser software was developed using Microsoft Visual Basic 6.0, and Microsoft Access database utilities with additional data acquisition functions provided by Measurement Computing Corporation.

The structure of software consisted of a controlling 'front-end' Visual Basic application software connected to an 'underlying' Access database containing plant configuration data, time domain and frequency domain configuration and processing data and finally historic data representative of physical vibration in various formats.

To the viewer the analyser main screen appeared subdivided, and on one side, a navigable expanding 'tree' with customer, route, machine, waypoint and vibration point 'name' information was displayed. The remainder of the screen presented information dependent on the 'tree' item selected. Generally, the selection of tree items, customer, route or machine initiated the display of helpful practical information such as site personnel contacts, or the location and attributes of specific machines. Yet, waypoint and vibration point selection, initiated the display of detailed data capture and processing information and importantly indicated abnormal machine conditions to the user via semi automatic analysis routines during data capture procedures. Furthermore, at the vibration point level, frequency domain data could be viewed in graphical format either in a frequency range window commonly referred to as 'a spectrum' or historically indicating the 'trend' of past data where the condition status of the data could be determined in relation to predetermined alarm datum's.

Benefits of the Standard Vibration Monitoring Analyser System to Manufacturing Industry

The standard vibration monitoring analyser was promoted and introduced to the vibration monitoring market primarily as basic overall tool aimed at customers who were contemplating initiation of vibration monitoring practices and for this purpose it provided the basic elements of data collection, frequency domain processing, frequency band analysis, historical and statistical analysis. Furthermore, the unit reported abnormal conditions relative to predetermined conditions at the location of data capture.

Yet, importantly, the unit presented a method of monitoring multiple sensors without the need to remove and reposition a free sensor common in most data collectors. The 'waypoint' attribute was considered to be beneficial since the time period of data collection is reduced, as is the potential for injury to the user, since user and waypoint can be positioned far from the location of the sensor. The benefits of the waypoint data collection procedure were thought attractive and therefore formed the basis of the next stage of the expandable vibration monitoring system. Consequently, the attributes of an 'automatic' waypoint will to be presented following.

AUTOMATIC WAYPOINT DATA COLLECTOR

In principle, from the outset of vibration monitoring a plant may be configured to have multiple 'manual' waypoints and therefore the task of capturing data is simply the practice of sequentially connecting to each. Yet, to reduce the number of waypoints and the time overhead incurred in relocating and connecting to each waypoint, the design for the automatic waypoint was set to accept up to 48 sensors as opposed to the maximum of eight in the original system. Furthermore, the hardware to acquire sensor data was transferred from the peripheral electronics of the original system directly to the waypoint and collectively with additional inherent software, the capability to store a set of data samples over a predetermined time period was added to the waypoint.

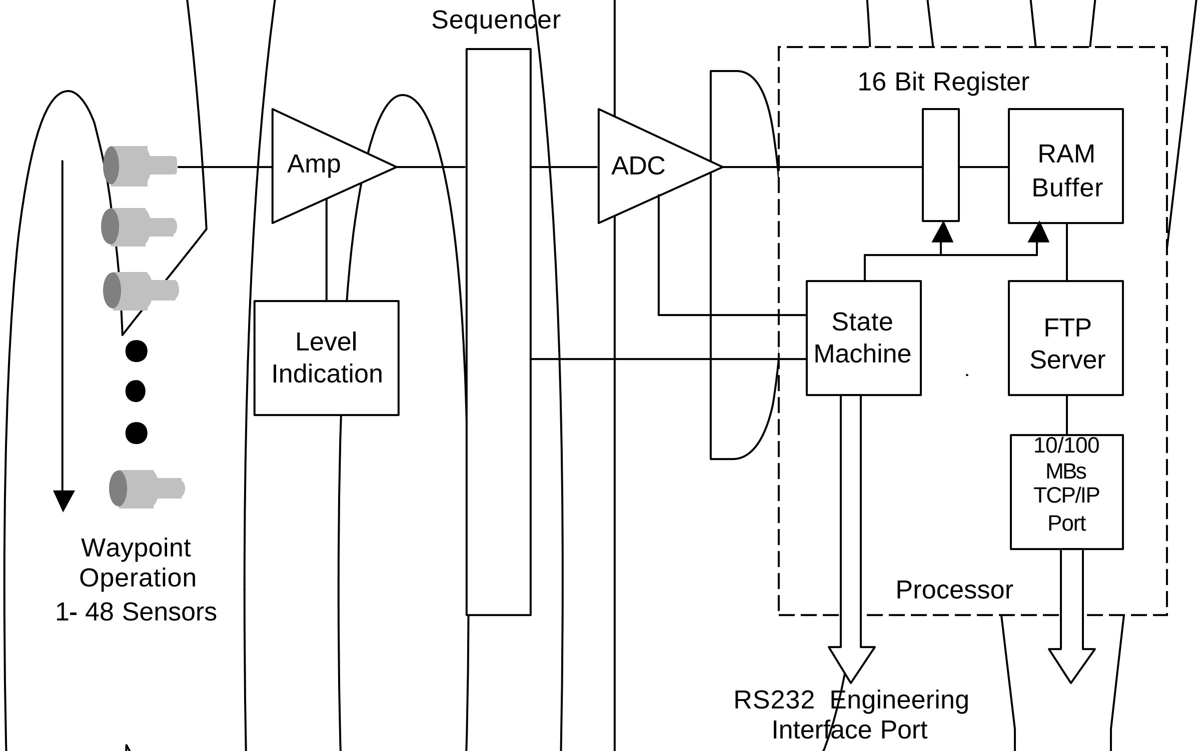

Figure 3 Function diagram of the automatic waypoint hardware.

Automatic Waypoint hardware

The hardware of the automatic waypoint shown in the block diagram of Figure 3 was very similar, fundamentally to that of the standard vibration monitoring data acquisition system, however since automatic waypoint system was based on static sensors, fixed gain amplifiers yet with manual adjustment were used, with the gain of the amplifier generally set so that a maximum input signal of 2volts peak to peak could be monitored, which equates to a signal of acceleration of 20g from a standard 100mV/g accelerometer. Moreover, an inherent processor was added which first provided control for a sequencer to select the required sensor for data capture and also set the sample rate and sample count of the ADC which, therefore established the time period of data capture for each channel. The time period for one cycle of the sequencer was therefore dependent on the sample rate and sample count of each of the channels, which generally for a nominal sample rate of 10kHz and a sample count of 6000, was 28.8secs. The sample rate of the ADC could be varied between 4.7kHz and 100kHz with the maximum number of samples per channel being 18000, selectable in multiples of 8 from 8 to 18000.

The data transfer procedure between the ADC and RAM buffer memory was basic. It followed that for each waypoint channel when a sample data request was initiated, an intermediate 16 bit latch register connected to the output of the ADC was first cleared, by writing its current stored data to the buffer memory appending an address equal to the required sample count, less the previous address count, less one. Subsequently, on completion of the sampling period the data available on the output bus of the ADC was then written to the latch register. This cycle repeated until the buffer address count equated to minus one at which point the waypoint sequencer incremented to the next channel. This procedure was controlled by a simple state machine as shown in Figure 3. Consequently, 16 bit binary data for each of the 48 channels was stored in the buffer memory for one full cycle of the sequencer before being overwritten with fresh data.

Automatic Waypoint Software

The waypoint was established, as indicated with a ram buffer, which was designed to hold a software file with a capacity of 1731456 bytes referred to as the 'datafile'. The structure of the datafile was set so that for each of the 48 channels it contained 36000 bytes of data in high low data pairs representative of the maximum 18000 samples. Furthermore, a 70 byte channel header was amended to the 'front' of each channel data set, which contained information regarding the channel number, channel description, sample rate, sample count, data and time. Subsequently, the datafile could be accessed using an inherent file transfer protocol (FTP) server application through a 10/100 MBs TCP/IP data port.

Automatic Waypoint Communications

Two ports were available for communication between the waypoint and peripheral devices. Generally, the 'datafile' previously discussed could be transferred between the waypoint host and the client analyser using FTP client server operations via the suitably configured 10/100 TCP/IP port. Additionally, an RS232 serial port was also available to configure all the operational attributes of the waypoint such as sample rate etc., which, could be achieved using any suitable equipment capable of running a VT 100 terminal application.

Benefits of the Automatic Waypoint Data Collector

The automatic waypoint data collector was based on the attributes of the manual waypoint and logically the original benefits are transferred yet the automatic system is suggested to add to these in the following ways.

The 'datafile' is always available and contains historical data, which generally is 30 seconds old. Now, given that the time period to download the datafile containing data for up to 48 sensors is approximately 30 seconds then this can be considered to be very fast compared with the manual 8 channel waypoint.

The downloaded data comes in a raw time domain format and hence alternative signal processing routines can be carried out providing other forms of analysis. Moreover, the data does not have to be representative of physical vibration since through minor modification of the buffer amplifier input any suitably conditioned process input may be monitored promoting full plant vibration monitoring possibilities.

Importantly, the task of down loading data does not have to be undertaken in the vicinity of the waypoint but can be carried out remotely using a standard 10/100 MBs network link. This attribute is significant, since this lends multiple waypoints to 'networked' and polled for data on a regular basis from a single location, which promotes further attributes of the expandable vibration monitoring system to be described shortly.

AN EXPANDABLE VIBRATION MONITORING SYSTEM

Data acquisition by the user can be accomplished in a 'manual' mode by simply connecting the computer via cable and 10/100MBs network card to the waypoint and further downloading the 'datafile' using most any FTP client. Subsequently, data could be processed to the frequency domain, quasi analysed for abnormalities and then stored in the database for future intimate analysis.

It should now be appreciated that through further simple development of the standard system software the manual data extraction procedure could easily be automated. Subsequently, the controlling software application to accomplish this could then be established in a supervisory computer and connected in a local area network (LAN) to the waypoints configured with unique identifying Internet Protocol (IP) addresses.

The attributes of the automatic waypoint are therefore fundamental to the concepts of the proposed expandable vibration monitoring system since data can be collected from the waypoint either manually or automatically. Furthermore, since the waypoint can be accessed by means of TCP/IP protocol, data can be acquire from global locations and therefore the prospect of a multi-site vibration monitoring system becomes a practicality.

GLOBAL VIBRATION MONITORING SYSTEM

The fundamental blocks of an expandable 'automatic' vibration monitoring system have previously been presented yet with global capabilities are brought together for appreciation in Figure 4.

Now, to fully create the automatic system the event driven visual basic code was modified into that of a quasi-procedural code format, with the addition of a polling engine, FTP client, alarm monitoring and remote reporting functions via simple mail transfer protocols (SMTP) and short message service (SMS) through global system mobile communication networks (GSM)

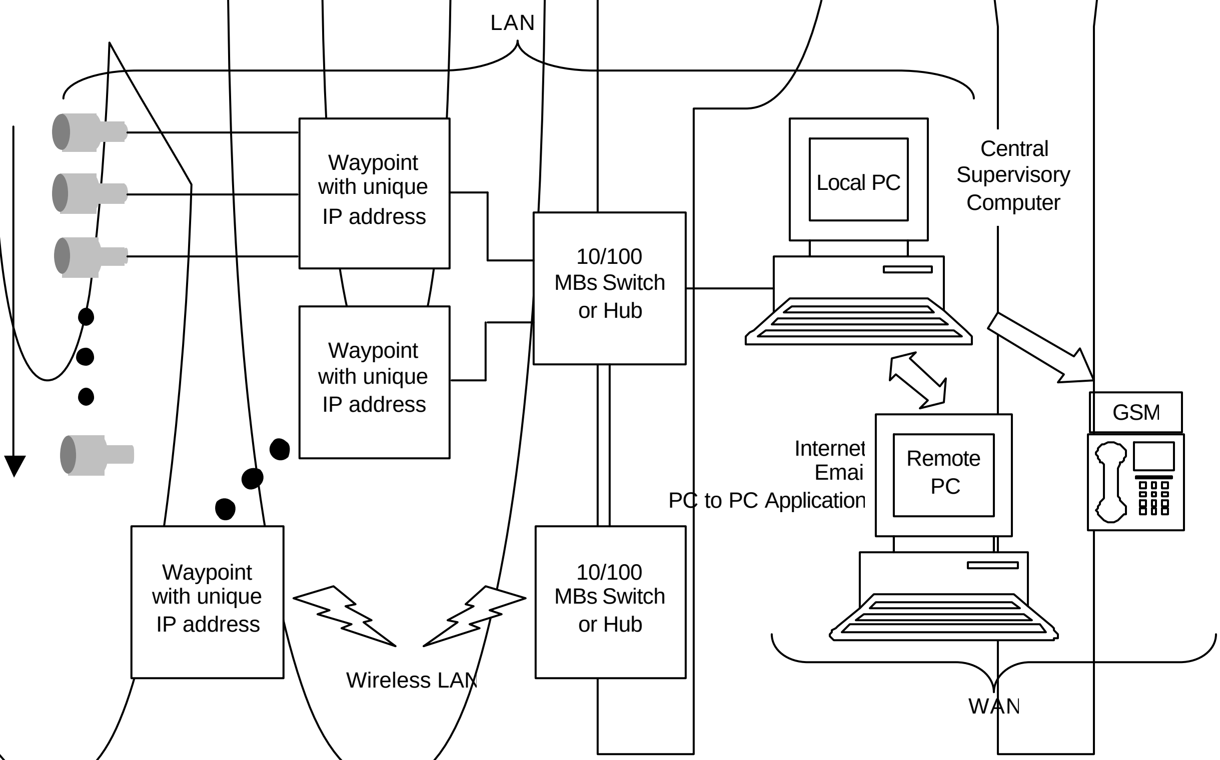

Figure 4 Block diagram of a proposed global vibration monitoring solution.

Generally, the polling engine provided a configurable time period between waypoint polling instances when FTP client would be instructed to ‘get ‘ the datafile from a waypoint. Following, successful transfer of the file from the waypoint to the supervisory computer, raw binary data would be extracted from the file and stored before being post processed into the frequency domain and further analysed relative to pre-set frequency bands. Finally, the database would be queried for exception alarms, which were then relayed locally to an alarm enunciator screen and remotely by means of SMTP and SMS messages. Furthermore, since the system is based on a TCP/IP network, this allows for bi-directional communications and hence provides means for navigation and consequently analysis and configuration of the plant system from remote global locations.

CONCLUSIONS

Through the attributes of the equipment described it is proposed that,

- A clear pathway exists for any form of manufacturing industry to implement vibration monitoring practices initially in an exploratory system using the hand held standard vibration monitoring analyser yet this still provides scope to increase the size and complexity of the system to that of the automatic global network described.
- The equipment described provides a clear alternative to existing commercially available equipment, which currently still invokes of maintenance personnel, an initial decision between manual hand held data collection or network based automatic data acquisition systems.
- This circumstance arises since the elements of the expandable system presented are reusable and re-configurable.
- Logically, the attributes of the equipment described must influence maintenance department peers initially in their decision making.
- If the benefits of a pilot vibration monitoring scheme are realised, approval of future system advances can be based on company economic status rather than the common maintenance benefit cost ratio judgment.

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