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## A Manager's Introduction to Turbo Machinery On-Line Diagnostics for the Power Industry

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## 1 Introduction

Noise and vibration is often easily noticed on general rotating machinery. However for larger turbo machinery, say greater than 25MW, such as steam turbines, electric generators, compressors, fans, gas turbines and pumps etc. incipient faults are not so obvious. Shaft speed, the ratio of bearing housing mass to shaft diameter, the type of bearing, lubricating system etc all influences a machine's time to failure. To ascertain the discrete condition of complex rotating elements requires an array of sensors continuously measuring and providing intelligent alarming for Operations. Stored data is available for detailed analysis in real time or viewed later for plant life cycle analysis etc.

This paper is an introduction for busy manufacturing managers who are expected to have a clear understanding of a plant's processes as well as the machinery. Amongst the wide range of tools to provide decision making information, Turbo Machinery On-Line Condition Monitoring Diagnostics offers the most responsive non invasive capability, enabling managers to schedule plant maintenance

## 2 Condition Based Maintenance (CBM) in India

Over the past 10 years most leading global vendors of CBM have been swallowed up by multi-nationals who now focus on their own interpretation of asset management. As a result only a few 'independents' remain, dedicated to the CBM niche where innovation will continue. Machinery condition monitoring in the 21st Century is however shifting to more on-line diagnostics, intimately linked to plant processes and operations. Companies are realising that the current practice of operating a small cell in an organisation doing 'break-down' vibration analysis is costly. The trend is now towards outsourcing such services or make use of an on-line consultant who has access to the raw data via the internet. Moving data and not people is much more cost effective if quality data is generated and accessible.

System Life Cycle is an essential business driver today, especially where consumer electronics like PCs etc are often considered obsolete in just three years! When managers select a Machinery Fault Analysis System, they will want one that is sustainable and provides long term user value. The facts of modern life are that all computerised diagnostic systems will have a limited life. However, this should not also apply to the prime machinery protection system measuring for warning and alarm/shutdown. Buyers must insist on spares and maintenance support from 15 to 20 years as a basic supply requirement.

*Selecting an electronic protection system that is interdependent such as a slave and master is a limiting arrangement. Those systems where the master monitor sends processed data to the slave analyser ensues early obsolescence of the whole system. An architecture that separates the Plant Protection Monitor (warning & alarm) allowing the Diagnostics to complement the system has a greater longevity and will prove a better investment in the long term. It also means original raw data is available for meaningful analysis whereas the master/slave configuration is limited.*

### 2.1 Condition Management Solutions

The three facts of rotating machinery are:

1. All machines vibrate
2. An increase in vibration suggests a developing fault
3. Each rotating element generates its own unique vibration signal

What do these three facts and condition management solutions mean to the plant manager?

### 2.1.1 Condition
Maintaining machinery on condition optimises process uptime, reduces maintenance costs and increases profits.

### 2.1.2 Management
Is a strategy for management to be in control of events rather than the other way round. Proactive machinery plant maintenance gives management a tool for productivity gains.

### 2.1.3 Solutions
A range of simple and elegant integrated solutions are available to meets the needs of the user. By creating customer value to match local operating environments, the end user can reap the benefits and early returns on the investment. This can only be achieved fully by a partnership between users and suppliers on a win-win basis.

Applying the **condition management solution** approach to capital intensive turbo machinery industries, such as Power Generation, is a proven formula towards zero break-down maintenance. On-Line Vibration Diagnostics is one of the technologies that contributes to this objective.

## 3 The Basics of Vibration Measurement

Vibration is the cyclic or oscillation motion of a body or component from its position of rest or its neutral position. Whenever vibration occurs there are four forces involved that determine the characteristics of vibration. They are:

1. The exciting force such as unbalance or misalignment
2. The mass of vibrating system
3. The stiffness
4. The damping characteristics

The characteristics that define vibration, and are needed to understand the behaviour of vibrating machinery, are illustrated in **Figure1**. The three prime key parameters are:

1. **Amplitude** (how much?) i.e. Displacement (microns), Velocity (mm/sec), Acceleration (g)
2. **Frequency** (how often the signal moves back and forward)
3. **Phase** (the time relationship between vibrating forces).

For simplicity, frequencies are stated in Cycles Per. Minute or CPM as this is easier than calculating in Hz when identifying orders or harmonics of a fundamental frequency.

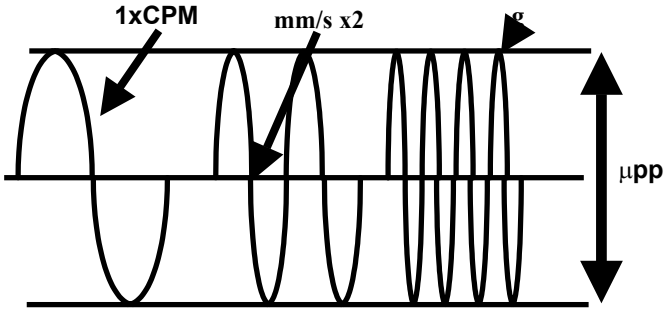



**Figure 1 – Types of Vibration Measurement**

When the three prime parameters are coupled with a machine's speed, load and effects of the process, a more precise diagnosis becomes essential for complex machinery. When applied to case mounted sensors on rotating machinery the selected measurement unit is determined by the rotor speed or frequency of the machinery elements. A general guide is as follows:

| Measurement Units | Definition | Units | Machine Speed Range in CPM |
|---|---|---|---|
| Displacement | The total distance a mass travels back and forth as it vibrates | microns peak-peak | <600 |
| Velocity | A measure of how fast the mass is moving back and forth. | mm/sec Peak or RMS | 600 - 120,000 |
| Acceleration | The rate of change of velocity | g's | 120,000 |
| Spike Energy™ | A technique for determining bearing and high speed gear meshing | gSE | Frequencies between 5kCPM - 50kCPM |

## 3.2 Vibration Analysis

Vibration can be represented in the Time or Frequency Domain that enables the analyst to identify suspect machinery elements. **Figures 3 and 4** are typical representations of the same data.

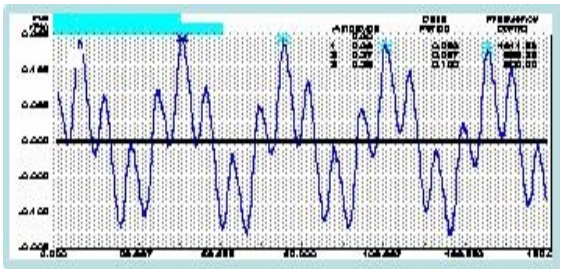


**Figure 3 - Time Domain (Waveform)**

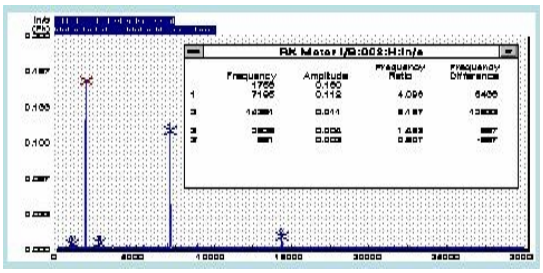


**Figure 4 - Frequency Domain (FFT Spectrum)**

The Time Domain format requires more skill to analyse but is indicative of repetitive vibration characteristics where complex signals illustrate a pattern. The frequency domain or vibration spectrum is easier to understand by the relationship between rotating machinery elements based on their speeds, base frequencies and associated harmonics.

## 3.3 Phase a Prime Tool for Analysis

Analysis of complex vibration frequencies (**Figure 5**) can often be a technical challenge. To better understand the signal relationships and machine response, phase measurement is essential.

Phase readings (0-360 degrees) can be obtained either with a strobe light or a 1xRPM pulse from a shaft reference point. In practice phase is used as an analysis tool to pinpoint problems and is a basic need for balancing rotors in place. Phase is a means of determining the relative motion of two or more vibrating parts of a machine or machines, particularly the driver and driven. Phase taken at one part of a machine only has relevance when compared to other phase measurements with a common reference, i.e. the same machine train and speed.

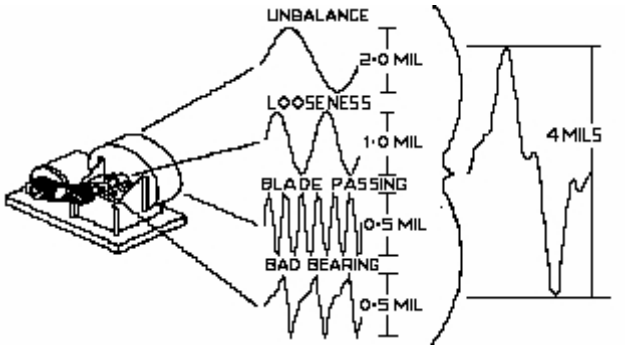



**Figure 5 – Complex Vibrations**

## 4 Off-Line or Portable Data Collection Systems

Prior to the development of the modern computerised portable data collector, bulky commercial vibration analysers were linked to XY or XYZ hard copy paper recorders.

Producing a machinery vibration signature (**Fig.6**) was a time consuming exercise and only a few machines could be analysed in a single day. Amplitude, Frequency, and Phase were standard measurements when most users undertook diagnostics. The main limitations were equipment portability, time taken and number of machinery signatures. Historical storage was also unreliable.

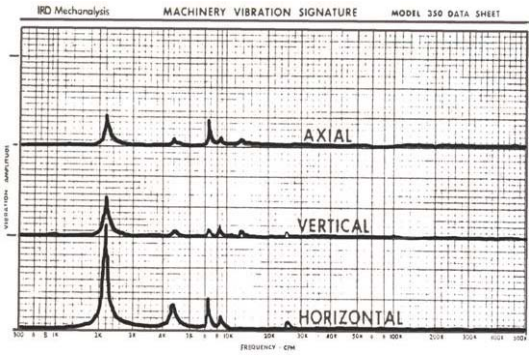



**Figure 6 –Vibration Signature on XY Recorder**

Following the onset of the powerful hand held vibration data collector with FFT (Fast Fourier Transform) and improvements over the past 20 years, signature collection became quite efficient. Most users now collect many hundreds of readings in a route and then undertake the vibration analysis at a PC remote from the machine. Generally only vibration amplitude and frequency signals are considered for analysis. Seldom is phase used due to difficulties of capturing the rotor pulse signals on a route. As a result despite the huge technology gains in signal processing, diagnostics has not improved much in line with product developments. This limitation makes all so called 'expert systems' basic aids as a decision analysis tool for the capable user. They cannot be relied upon for intelligent alarming.

Other shortcomings of the portable digital data collector and digital meters are that they have numeric displays (**Fig.7**) as against the traditional analog meters (**Fig.8**). Vibrations are seldom stable; the digital display keeps changing unless highly damped or averaged. Over the years those new to vibration analysis have not appreciated how much information is being lost by the apparent 'new digital technology.' The moving coil analog meter continues to present a much more representative indication of machinery vibrations, process fluctuations, peaking and even bearing rubs etc. None of this is possible with the so called 'modern' digital meter.

**Figure 7 – Digital Display**


**Figure 8 – Analog Display**

Perhaps the most disturbing issue with off-line data collection is that samples are seldom captured more than monthly and some at even longer intervals. This makes proactive maintenance based on such practices less relevant and almost useless. In fact it has been seen at many plants that investments in portable data collectors and software are not bringing the intended returns. Instead of frequent high volume FFT sampling the equipment is used for pre break-down emergency analysis when Operation's reports a machine is shaking itself to bits!

For Turbo Machinery, vibration analysis can be complex and as such the portable off-line approach is quite unsuitable. Strategic machinery condition is better understood by a high rate of consistent on-line sampling from permanent sensors such as vibration, phase and process parameters such as load, speed, temperature etc. This is illustrated in the Section 11.2 on Diagnostic System Outputs but selecting the right vibration monitoring system has to be addressed first.

## 5 How to Select a Vibration Measurement System

The following summarises the questions a manager needs to ask when proposing a condition management solution for an organisation new to the technology:

| **Objectives, Budgets, Skills, Needs** | **System Capabilities** |
|---|---|
| What do we want to achieve? | On-Line Monitoring (warning, alarm & shut-down by operator decision) |
| Budget for equipment & Training? | On-Line Protection (strategic & high speed requiring automatic alarm & trip) |
| Core competency? Knowledge level? | On-Line Diagnostics (associated with Protection System) |
| Number & type of machines to be monitored? | Networking data (distributed to DCS and Operator Displays) |
| Integration with plant processes, computerised maintenance management systems (CMMS) ? | Vibration and performance monitoring software (for machine life cycle analysis) |

The most important aspect when selecting a condition monitoring system is that it must be part of an overall company strategy to improve plant availability. It must also have the commitment of executive office, operations and maintenance managers as part of the company strategic plan. Whichever system is selected, it will not return the benefits or expectations of all parties as it will be seen as a gadget and viewed in isolation of the main business activities.

This paper now focuses on the predictive capabilities of a Mechanalysis-On-Line vibration based condition monitoring programme for strategic Turbo Machinery.

## 6 What is On-Line Turbo Machinery Diagnostics?

It is a system of integrated hardware and software measuring machinery performance 24/7 on-line in real time. It will present, easily recognisable information on machine status to enable Operators to take preventative decisions. It can also be used to monitor process quality such as defective steel or paper rolls affecting the product. Raw data is continuously captured and stored so that Machinery Diagnostic Engineers can study steady-state, machinery start-up and post trip conditions in order to pinpoint incipient machinery or process faults. Not all diagnostic systems are intended for 24/7 data capture and can be moved around the plant for investigative or research purposes. This portability offering flexibility is a cost effective solution for many users, particularly OEMs.

We now need to make a more detailed comparison between off-line and on-line systems to gain a better understanding of the benefits and short comings of both on and off-line systems.

## 7 Off-Line versus On-Line Data Collection Systems

The decision whether off-line or on-line is usually quite straightforward. The former is a periodic measuring system with remote analysis whereas the latter continuously measures, protects, enabling warning and shutdown alarms.

Generally the off-line application (**Fig.9**) is selected due to plant layout logistics against the cost of installing and maintaining an on-line system.

It is often assumed that the apparent lower cost of an off-line system offers more benefits. In many cases this may not be the best decision. The following comparison is not exhaustive but gives some of the issues to consider:

**Figure 9 – Periodic Vibration Data Collection**

### 7.1 Off-Line Vibration System Comparisons

Understanding the benefits limits of any system will set the expectation realistically; the table below identifies the main issues:

**Positives**

1. Portability
2. Unlimited readings
3. On the spot visual faults (oil leaks etc.)
4. Data Collection is relatively simple
5. Powerful analysis capability (with phase)
6. On site rotor balancing
7. Links with other NDT data
8. Non invasive
9. Establish without interfering with installed plant systems
10. Basic training takes 5 days
11. Relatively low initial investment
12. Lower cost per measurement point

**Negatives**

1. Taking the right reading (prone to error)
2. Limited with critical machines
3. Sensor hand held readings (case mounted)
4. Awkward taking NCPU data
5. Skilled labour intensive
6. Frequency of data vs. load changes is limited
7. False alarms due to process variables
8. Faults are only reported when looked for
9. Usually limited to amplitude & frequency measurement
10. Analysis will be limited without phase data
11. Often only used in fire fighting mode
12. Manpower turnover
13. Consumables: cables, battery, sensor
14. Portable instrument fatality, then no data
15. Data is seldom distributed
16. Only seen as a maintenance function
17. Rarely integrated with CMMS
18. Seldom visible to Operations
19. Re-invest every 4 years

Many Indian companies are realising that it is more cost effective to employ a Consulting Service Company to operate its vibration based condition monitoring programme. Contract CBM has better skilled continuity compared to high staff turnover of in-house managed programmes.

The performance of on-line diagnostics systems (**Fig.10**) has improved markedly over recent years. Further, the price per measured point now makes the choice for an on-line diagnostic system a practical proposition.

The system offers high quality information and greater user value than ever. Both Operations at the Central Control Room (CCR) and Maintenance can have customised networked data available 24/7 to suit their specific requirements. Headquarters also has access to any or all data for strategic analysis purposes.

**Figure 10 – On-Line Diagnostics**

## 7.2 On-Line Vibration System Comparisons

The strengths and weaknesses of a Mechanalysis-On-Line Multi-channel System are not exhaustive but the main issues need to be appreciated as they will influence the purchase decision.

**Strengths**

1. High quality data available for machinery analysis
2. Data collection automatic and continuous
3. Consistent data collection
4. Instant alarms machine faults
5. Amp, Freq, Phase, load collected
6. Very powerful analysis capability
7. Links with other process data
8. Data a is distributed to DCS
9. Visible to Operations & remote services
10. Works with or without protection monitors
11. Ideal for plant life assessment

**Weaknesses**

1. Measurements limited to number of installed sensors
2. Needs installed sensors wired to CCR
3. Economic with critical machines
4. Analysis can be complex
5. Requires skilled diagnostician or a remote service
6. Cost per measurement point
7. Can be a relatively high initial investment

## 7.3 Estimated Cost Per. Measured Point

Cost analysis is a common issue and the comparisons below are likely to generate active debate:

*Assumptions: staff costs are taken as the same*

| **Off-Line Measurement** | | **On-Line Monitoring** | |
|---|---|---|---|
| Hardware | Rs 9 Lakh | Hardware | Rs24 Lakh |
| Software | Rs10 Lakh | Software | Rs10.5 Lakh |
| PC | Rs 0.5 Lakh | Sensors x 800 | Rs14.4 Lakh |
| Maintenance pa | Rs 0.5 Lakh | Maintenance pa | Rs 0.5 Lakh |
| | | | |
| **TOTAL COST** | **: Rs20 Lakh** | **TOTAL COST** | **: Rs49.4 Lakh** |
| Machines | : 50 | Machines | : 50 |
| Samples per machine | : 16 | Samples per machine | : 16 |
| Samples 2 p/month | : 1,600 | Samples 24avg p/day | : 19,200 |
| **Cost/sample Rs** | **: 1250** | **Cost/sample Rs** | **: 257** |
| Greater number of machines, low quality data needs additional tests. Operator Safety | | Higher sample rate & quality, additional machine points reduces costs | |

The cost comparison per point calculation can be skewed in any direction one wishes. The key message is that frequency and quality of sampling offers greater direct return on investment than occasional readings of doubtful quality. The presence of a CBM system that is not properly managed will lull the company into a false sense of security when the reverse will be true.

## 8 Criteria for Hardware & Software Selection

A guide to selecting both hardware and software is always difficult to establish but the following criteria covers the main elements.

**Hardware**

1. Proven reliability
2. Flexibility for addition of on-line inputs
3. Relative cost to machinery investment
4. Ease of use hardware with software
5. Frequency & Dynamic range
6. Measurement parameters
7. Operation & Display types
8. Transducer types & interface
9. Phase & Speed reference inputs
10. Data communications
11. Number of years spares available
12. Upgradeability
13. Local support services with core competence
14. Obsolescence policy and process

**The Software**

1. It must have standard functions & features for ease of use
2. Defines what type of data is collected
3. Defines how dynamic & process data is collected
4. Records process information
5. Will have intelligent alarming that automatically generates reports
6. Distributed data available for all to view of plant condition
7. Data export capability for analysis of process performance
8. Hard copy reports easy to generate
9. Links with CMMS
10. Exports data to other plant performance management reports
11. Number of years supported
12. Upgradeability
13. Local or web support ensures response and reduced risk
14. Obsolescence policy and process

## 9 Who Needs On-Line Condition Monitoring Systems?

Where personal and plant safety are prime concerns, protection monitoring is essential. Most high speed turbo machines have a short time to failure; bearings fail exponentially and early indications of fault development need continuous

machinery diagnostics monitoring. Periodic weekly or monthly data acquisition is not only high risk but seldom an engineering solution.

The responsible operator/owner of production plants with high speed turbo machinery will undertake a machinery risk analysis. Steam and gas turbines, high speed compressors (e.g. Syngas), on-shore and off-shore high production plants etc. would be included when deciding the level of precaution necessary.

Analysing turbo machinery at high speeds with confidence is only achievable with a responsive on-line data acquisition system. Faults such as bearing rubs, sub synchronous signals, oil whirl; dynamic shaft centreline, un-balance, alignment, gear meshing etc are easily detected. Hydraulic and cavitation effects as well as combustion chamber characteristics, combustor imbalance and dynamics are amongst the many challenges facing engineers. Most of these potential machinery problems can only be identified with an array of well positioned sensors continuously collecting data at high speed for analysis on-line in real-time. Correlating machinery readings with the process, such as temperature and load, completes the picture. The skills required for undertaking the diagnostics are similar to any user of off-line data collection skilled in data analysis. However, a thorough understanding of machinery dynamics is required to optimise the data presented. Most CBM equipment vendors offer training but expertise is built upon with frequent usage.

Getting started commences with identifying the plant's needs and challenges towards the *Zero Breakdown Maintenance' Objective*. When considering the investment in the plant machinery and down time lost production, the investment to protect this by on-line machinery condition monitoring is a fraction of the possible losses. Therefore, the economic argument is usually overwhelming for on-line protection and diagnostics systems.

## 11 Turbo Machinery Protection & Diagnostics

As part of Mechanalysis (India) Ltd 'Systems Integration' business strategy, the company has recently partnered with Beran Instruments of the UK. The synergy of products and complementary company fit offers Indian industry an unrivalled opportunity and new concept in turbo machinery protection and diagnostics. MIL provides essential yet economic Protection Monitors with Alarm and Trip functions, outstanding reliability and manufactured in India. Beran completes the picture with its highly proven and comprehensive Multi-channel Condition Monitoring Diagnostics system. These complementary condition management solutions can also be supplied individually.

The system architecture (**Fig.11**) outlined below is compared to most mainstream monitor designs that function as a Master and Slave arrangement. This has been the trend over the past 15 years to undertake more signal processing in the master unit then transmit reduced data for analysis without slowing down networks. As a result original time wave form data is lost and detailed historical analysis is not possible. The DRPP (dual redundancy parallel processing) system offers greater reliability with no inter-dependency. The Protection Monitor focuses on protection while the Diagnostic System efficiently manages and stores raw data for intelligent alarming at Operator's displays as well as allowing post analysis review.

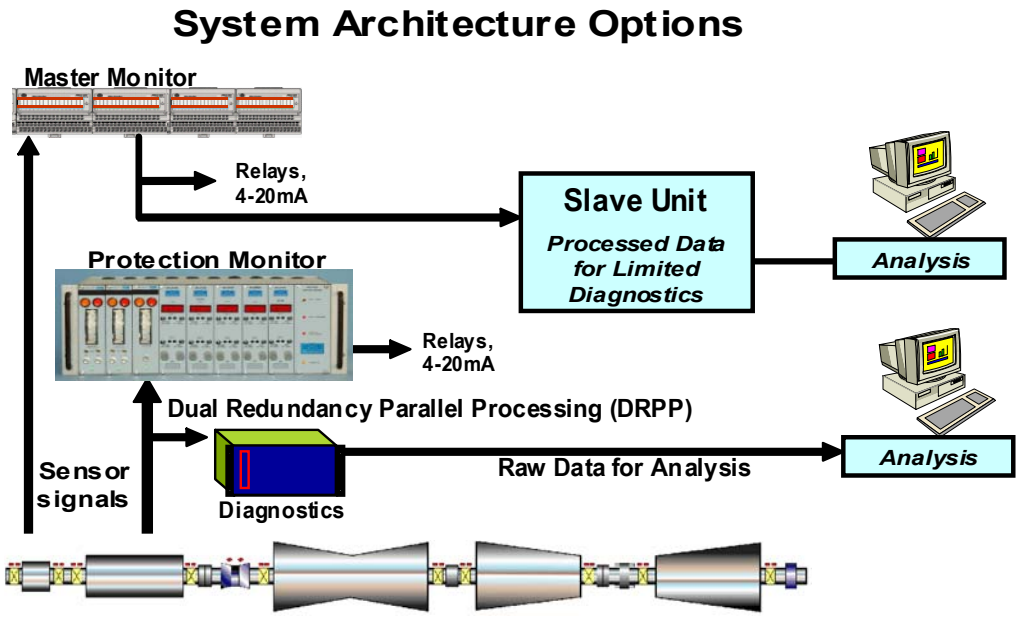



**Figure 11 – Master-Slave versus Dual Redundant Parallel Processing Architecture**

The DRPP System is described in more detail as follows:

**Protection Monitoring System**
The Mechanalysis model MIL8700 machinery protection monitor with sensors offers independent alarm and trip relays for up to 16 channels per 19" rack.

**On-Line Diagnostics**
The Beran model 766 unit accepts the sensor signal for multi-channel data capture and generates a wide range of diagnostic reports. The key features are:

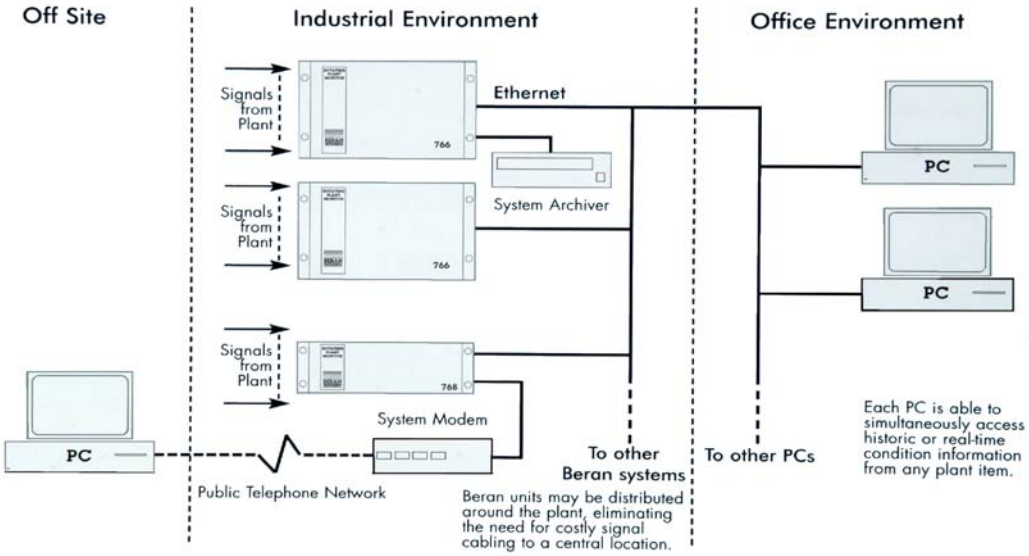
**User Man Machine Interface**
- Easy to use and configure Software
- MS Windows-based user front end
- LAN, WAN or Dial-Up compatible

**Data Handling**
- Fast data capture
- Comparison of real-time data with historic
- Remote access to real-time & historic data

**Effective Functionality**
- Powerful alarm functions
- Automatic plant-state detection
- Expandability through modular design

## 11.1 Open Communications

A key requirement of modern systems is open and net-workable communications as shown in the schematic below. It enables multiple machinery to be monitored in real time and able to capture data on all machines at the same time in the event of a complete plant trip as well as machine start up routines. The system speed is not compromised during this multi-tasking situation.



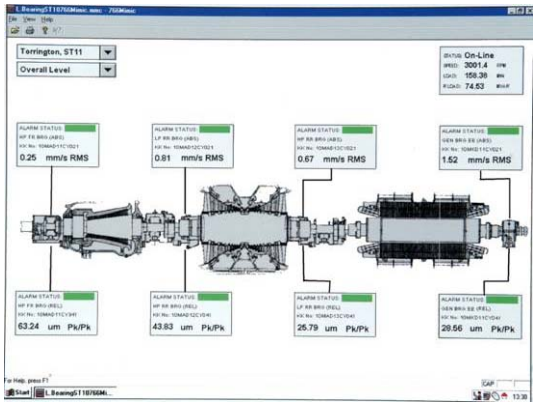

**Network Architecture – LAN or WAN and Modem Access**

Fully Net-workable, communications on LAN or WAN, the system is available on a building block arrangement. Additional units can be added as the need arises without compromising the system performance. Subsequent data acquisition devices do not require repeat software modules as that initially purchased can be extended as the site system expands. Static data can be transmitted by serial link to the Beran unit thus saving wiring costs and simplifying data exchange.

## 11.2 Diagnostic Information Outputs

Customised MIMICS are available with Operator access to real-time or alarm log views. Operations have access to machine status reports to suit their requirements. Maintenance and Diagnostic engineers or a remote Support Services can study issues in greater depth at any time, particularly when comparing current with historical data. An important requirement of any system is that it provides decision making information and not simply data.

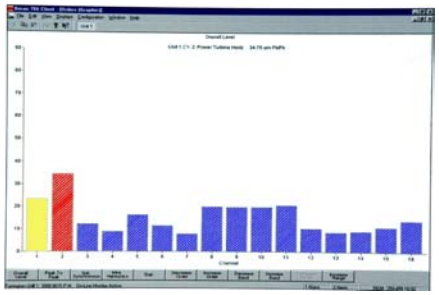
1. MIMICS – Customised Man Machine Interface
2. Windows Familiarity – User Friendly.
3. Context Sensitive Set-Up, incorporates a Help Wizard
4. Intelligent Alarming
5. Bargraph/Histogram: current overall values for 16 channels
6. Single bearing order, magnitude & phase with plant load to time
7. Reconstructed Orbits across 4 bearings Waterfall
8. FFT waterfall with average historic & real-time
9. Run-up of single bearing in polar format with vector change etc.
10. Multi-plots – 3 bearings with respect to machine speed using 'Y' axis
11. FFT with zoom along 'Z' axis



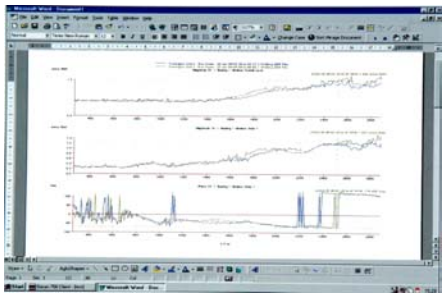

**Plant Operator MIMICS**

## 11.3 Selected User-Definable Graph Displays

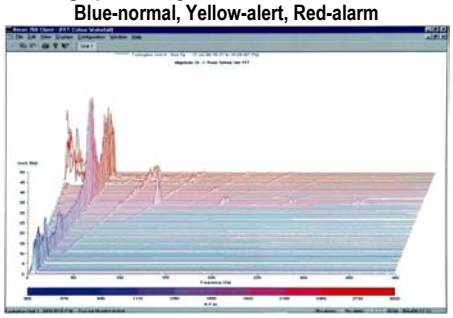
It is often said a picture tells a 1000 words, the selected screens below could indeed justify a 1000 words but the purpose of this paper is to expose the Manager to the variety and power of the Mechanalysis-On-Line diagnostic system outputs. The following are a small example of the almost limitless number of selections possible.



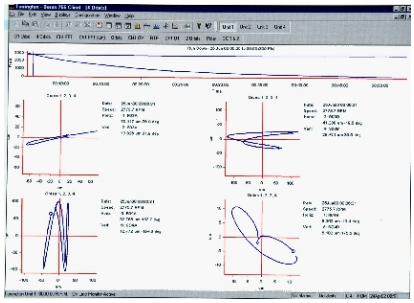
**Bargraph / Histogram : current overall values**
**Blue-normal, Yellow-alert, Red-alarm**



**Bode plots, Load and Phase**



**Waterfall Display**
**Colour parameter changes with speed**



**Orbits**
**Can also be Reconstructed**

## 12 Global Users

All successful systems will gain global recognition and the Beran On-Line Diagnostic system is no exception. Users are diverse as Australia, Canada, Denmark, Egypt, France, Finland, Germany, Hungary, Italy, Portugal, UK and USA; India is currently under consideration. The Mechanalysis MIL8700 Protection Monitor has been in use for over 10 years with more than 230 systems in India and abroad enjoying unrivalled reliability at an economic investment. Beran applications of over 12,500 Channels measured in excess of 220 users in the UK alone and 20 years of continuous support speaks for itself. Other well known users are Alstom, Ansaldo, Siemens, Nuovo Pignone, David Brown, British Nuclear Energy Magnox, British Nuclear Fuels, Eon, First Hydro, EDF (France), Scottish Power, Npower, Scottish & Southern, Industries UK. With such a pedigree, the risk for a potential new user is minimised and expected value assured.

## 13 The Benefits of On-Line Condition Monitoring Diagnostics

The benefits of on-line condition monitoring diagnostics are many. Primarily, is the greater Operator confidence in strategic TurboMachinery health and consequent increased plant availability. Advanced warning of component failure and accumulating machinery behavioural trends for optimising production and system design are readily realised. Subsidiary features of the diagnostic system are summarised:

1. High quality data available for strategic machinery analysis
2. Historical data can be reconstructed e.g. Orbits
3. Automatic un-attended data acquisition
4. Links with other process data for overall efficiency analysis
5. Consistent comparable data for analysis
6. Data is distributed to DCS
7. Alarms machine faults instant to Operator's displays
8. Amp, Freq, Phase, load collected - overcomes false alarms
9. Works with protection monitors or independently
10. Rebuild historical data to compare with current for detailed comparisons and change
11. Very powerful analysis capability – pre & trip fault review
12. Ideal for plant life assessment

## 14 Future CM Trends in Industry

Industry will continue to use the off-line vibration data collector but it will play a reduced role while remaining an economic solution. Industry is fast recognising that for **TurboMachinery On-Line Multi-Channel Diagnostics** is more dependable and consistent for optimising plant performance than off-line systems. The ability to undertake Plant Life Cycle analysis with on-line data analysis systems is an essential long term strategic planning tool. Operations and maintenance are converging and distributed data helps this process. Remote analysis by experts operating from central or back offices will evolve as confidence is gained, even though the mature technology and service exist today. On-line data offers opportunities for realistic expert analysis and intelligent alarming in real time but most systems are rule based requiring analysts to take the decisions. Mechanalysis India is at the forefront of industry trends having invested heavily to meet the future needs of the modern business manager but continuous improvement will be essential to meet industry's growing demands for technology solutions applied to strategic turbo machinery.

**With On-Line Condition Monitoring Diagnostics, the TurboMachinery Managers will be in control of events rather than the other way round."**

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