# Broadband Vibration Monitoring of Gas Turbines

## Industrial gas turbines

The use of accelerometers for vibration measurement on bearings, casings or structures is best practice on gas turbines. The measurements are often referred to as "absolute" vibration, to compare them against the "relative" measurement of displacement (which is preferred for the vibration measurement of journal bearings). In general, aeroderivative and lighter industrial gas turbines use exclusively absolute measurements, whereas heavy duty gas turbines employ relative measurements. However, the use of accelerometers on heavier machines at selected locations is quite common. When considering absolute measurements, there are three modes of signal evaluation, namely:

- Broadband (BB) or reduced band (RB)
- Dual path (DP) – two or more frequency bands
- Narrow band (NB) frequency with tracking filter

This application note discusses the **broadband** implementation.

## Fundamentals of broadband monitoring

Broadband monitoring is simply the application of a band pass filter to the incoming vibration signal (→ **fig. 1**). The High Pass (HP) and Low Pass (LP) components of this band filter are fixed. Generally, the band pass filter is defined to conform with an international standard such as ISO-2372, or a national one such as VDI-2056. The bandwidth chosen must cover the whole of the speed range of the monitored turbine for the vibration level value to be of any value. ISO-2372 defines the measurement of velocity (mm/sec RMS) between 10 and 1 000 Hz.

Integration – from acceleration to velocity, or from velocity to displacement – is often performed, but no further processing takes place in simple broadband monitoring. This means all frequency components of the vibration signal in the selected band are present.

The advantage of this is simplicity; all significant vibration sources contribute to a single value, commonly known as the "overall level". The overall level being either the peak-to-peak (Pk-Pk) value of the incoming complex waveform, the peak (Pk) value, or the root mean square (RMS) value.

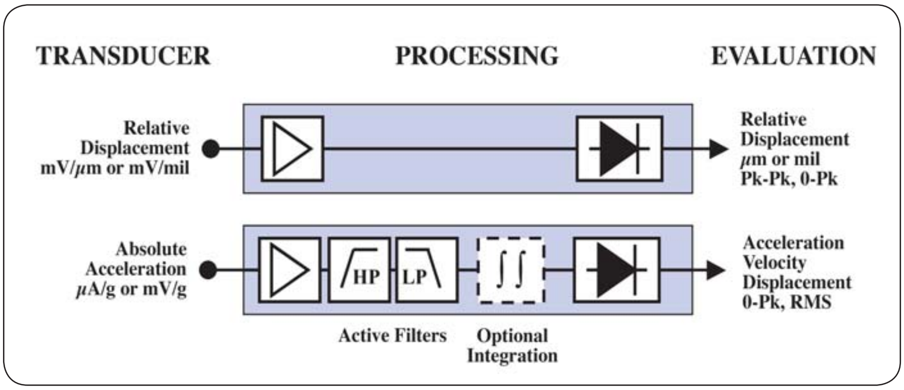


*Fig. 1. Signal path – broadband (BB) or reduced band (RB) monitoring.*

The disadvantage of the broadband approach is that it is impossible to determine the most likely source of a high vibration signal, other than by association with the location of the sensor itself. For example, a high overall broadband level from a sensor mounted on the compressor section of the gas generator would suggest a likely problem with the compressor. However, this may not be the case, especially on a lighter machine where external influences have greater effect.

**Fig. 1** illustrates that relative displacement sensors typically have no processing applied, as they must measure down to DC, and the measurable limit of displacement determines the highest frequency of interest.

## Transducers, conditioners and transmission

The choice of transducer, its quality and performance, as well as its location on the machine, are crucial criteria for the efficiency of any vibration monitoring system. The choice of transducer is dictated by two fundamental considerations:

- Environment – particularly safe or hazardous area (Exi) requirements
- Operating temperatures

Accelerometers are the most common sensor employed in broadband applications, and most types have Exi versions. The main factors that limit the temperature a transducer can withstand is the location and quality of its signal conditioning electronics. All piezoelectric accelerometers produce a charge output proportional to the acceleration of the surface to which it is mounted. This must be converted to voltage and amplified by a charge amplifier to an output in mV/g.

Most general purpose industrial accelerometers (which have in-built electronics) will be adequate for temperatures up to 100 °C *(212 °F)*, an example being the models CMSS 2100 or CMSS 793-EE from SKF. However, most gas turbines require higher temperatures. The Vibro-Meter CE type sensor family (again, with in-built or attached electronics) is suitable up to 350 °C *(660 °F)*.

For higher temperatures, the charge amplifier must be removed from the sensor area completely; the Vibro-Meter CA type can withstand temperatures up to 650 °C *(1 200 °F)*. The pC/g signal is converted by charge amplifier IPC-704 to a current modulated signal (µA/g). Optionally, the signal is integrated to velocity (µA/mm/sec). **Fig. 2** illustrates three possible chains in an Exi application.

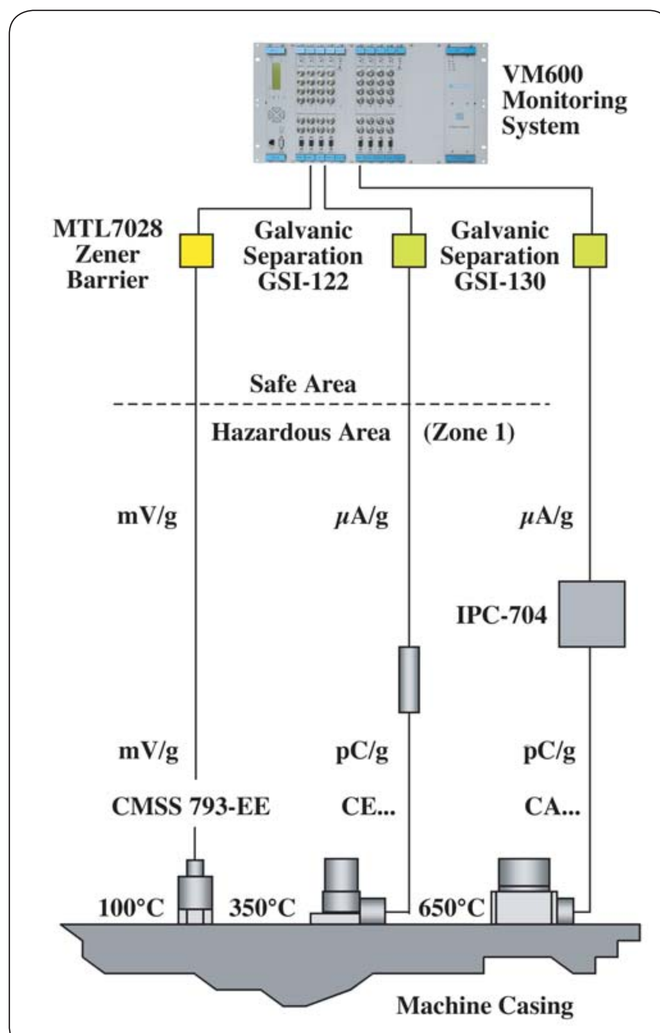


*Fig. 2. Accelerometer chains.*

Transmission of the signal to its associated monitoring electronics is determined by the sensor type and the transmission distance. The mV/g output of the CMSS 2100 or CE type family is typically between 350 to 500 m *(380 to 545 yds)* with reasonable quality cable. Higher quality low capacitance cable can increase this distance, but at greater expense.

The µA/g output of both the CA type and CE type can be transmitted over distances between 1 000 to 2 000 m *(0.6 to 1.2 mi.)* in a wide frequency range (up to 40 kHz) without significant signal attenuation, but the high quality and temperature rating of the transducer usually commands a premium price.

All the factors mean that the choice of acceleration sensor is evaluated in great detail by the gas turbine manufacturer and approved as fit-for-purpose by engine type. **Table 1** shows a table of engine types that employ broadband monitoring, with approved sensors.

**Table 1**

**Industrial gas turbines using broadband monitoring**

| Manufacturer | Type | Transducer | Conditioner | Electronics |
|---|---|---|---|---|
| **Sulzer-Escher Wyss** | Type 3<br>Type 7<br>Type 10 | CE310<br>CA201 | IPC704 | Sulzer System |
| **ABB** | Type 8<br>Type 11 | CE310 | | Vibro-Meter MMS |
| **Siemens** | V.84<br>V.94 | CA201 | IPC704 | Vibro-Meter MMS |
| **Rolls-Royce** | Olympus<br>Avon | CE134 | | Vibro-Meter or Other |

## Example application

**Fig. 3** is a measurement point diagram of a THM gas turbine driving a MAN (Hispano-Suiza) gas compressor. Two measuring chains monitor this gas turbine – one on the compressor section of the gas generator and the other on the power turbine. The transducers are located on the machine's external structure, following recommendations of the manufacturer. Two other measuring chains monitor the driven machine, a high pressure radial turbo compressor. All four chains measure the absolute (casing) vibration and form together a four channel broadband monitoring system, perfectly suited for this kind of machine. Although only the power turbine location requires a medium temperature rating (350 °C / 660 °F), the same transducer is selected throughout the chain to simplify maintenance, in this case a Vibro-Meter CE 134 (Exi version). The evaluation of the processed signal is performed in terms of velocity, displaying mm/sec RMS between 10 and 1 000 Hz.

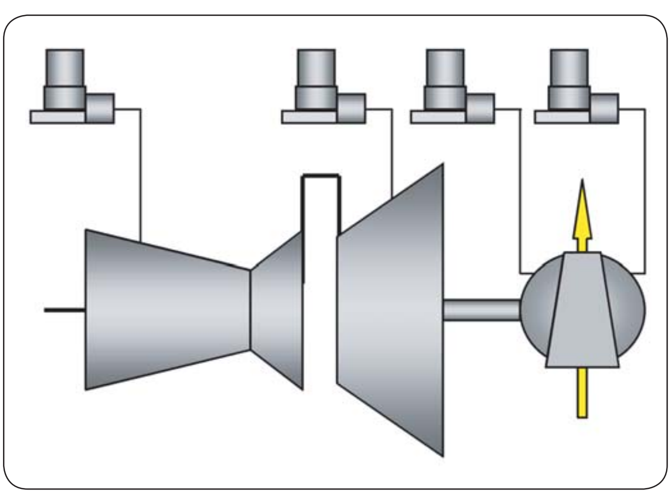

***Fig. 3. Example application.***

# Processing and evaluation

The evaluation of the sensor signal in a broadband application follows the principle shown in **fig. 1**. The evaluation takes place in a monitoring system such as the VM600 system illustrated in the chains of **fig. 2**. The evaluation may be realized in different manners utilizing either acceleration, velocity or displacement. The VM600 system assigns a single channel input per sensor.

From this single input, two processing paths may be assigned to the same input. The classical broadband solution is the display of velocity (mm/sec RMS or inch/sec RMS). The monitoring of the entire broadband occurs with this parameter, and two alarm set-points are defined – ALERT and DANGER. The latter may be used for machine shutdown in order to protect it from excessive vibration levels. The VM600 is a multi-channel digital monitoring system with a single monitor card – the MPC-4, fully programmable for virtually all applications. Each MPC-4 card supports four dynamic channels and two speed channels. Hence, to accommodate the application in **fig. 3**, a single MPC-4 card would be required. **Fig. 4** illustrates the input programming to support the CE type sensor used in the example application. **Fig. 5** illustrates the processing programming to implement the associated broadband monitoring.

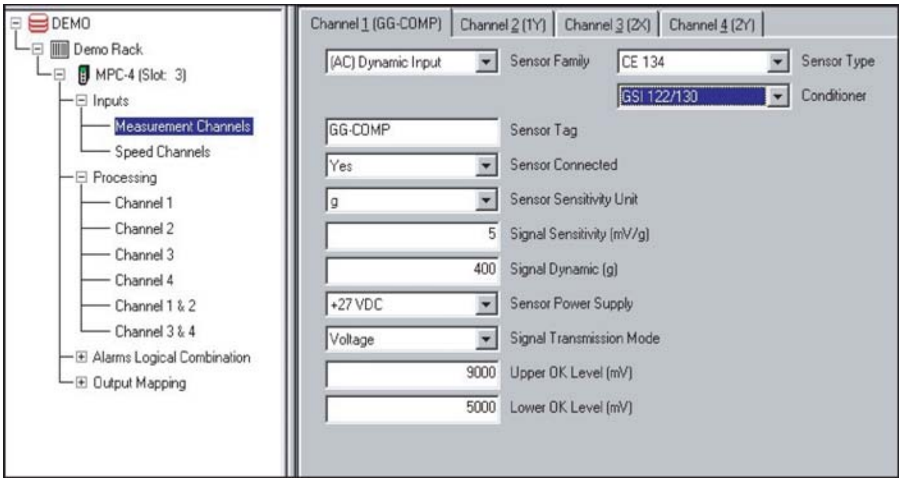


*Fig. 4. VM600 input programming for example broadband application.*

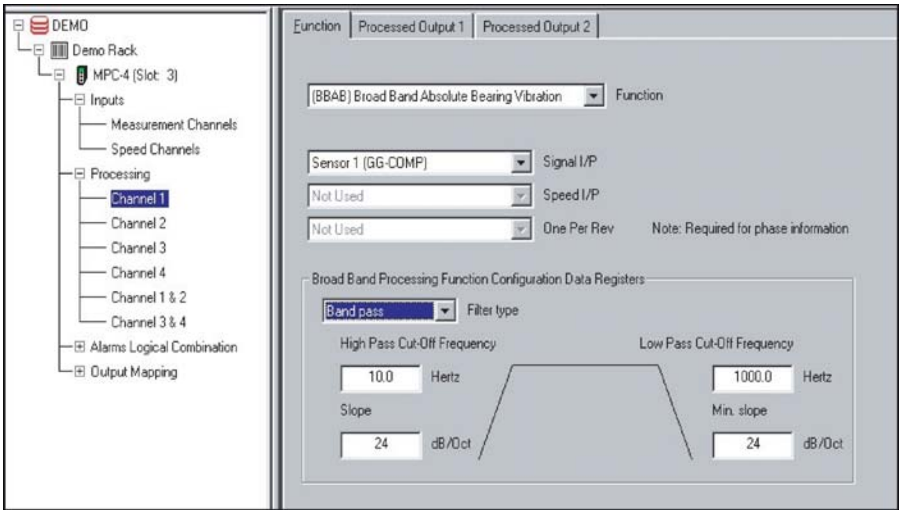


*Fig. 5. VM600 programming for example broadband application.*

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