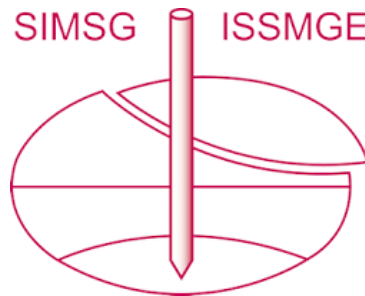


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# Instrumentation and Geotechnical Monitoring using VSPECT @ technology for the analysis of vibration sensor data.

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**ABSTRACT:** The demand for geotechnical monitoring increases as technology develops, it is known that with the new regulations for Dams, Slopes, Hillside Monitoring and etc ... that the acquisition of data of several types of sensors makes the measurement of parameters and real-time data analysis that is easier, safer and more concise, but simply collecting the data without verifying how much the analysis is being hampered by the noise generated by the environment around the equipment is a mistake, one must determine with what precision we are working as well as the degree of sensor performance and data acquisition to maintain a high degree of fidelity among observed data.

The request for data acquisition systems grows as many sensor models appear on the market, Campbell Scientific Inc. has verified that there is a difference between the data collected on the vibrating string sensors and the data presented in the acquisition of data, the simple data collection using an analysis of the period mean in the time domain makes the measure inaccurate and often fails. Because the environment is the sensors will be electrical interference, as well as noise generated by the cable patch and etc ... The solution for measurements of vibrating strings is the spectral analysis that takes into account the use of Fast Transforms of Fourier to smooth signal noise, eliminate false alarms in order to get a clean sensor response. The joining of state-of-the-art equipment with high data capture power, whether dynamic or static, with the development of state-of-the-art technology makes the Campbell integration system the strongest, most robust and most developed in the market. This technology (VSPECT@) aims to improve the verification of the vibration sensor signals that have high life expectancy, and also a high tendency to capture noise from the environment.

**KEYWORDS:** Vibrant Strings, Fourier Transform, Noise, Data Collector, Analysis, VSPECT.

## 1 INTRODUÇÃO

The understanding of geotechnical engineering as we know it began in the early eighteenth century, one of the greatest examples of problems related to the load capacity of the soil in the construction of structures is dated before the eighteenth century, known as Leaning Tower of Pisa located in Italy, its Construction began in AD 1173 and at its apex reached 5 meters off the plum thanks to a fragile layer of clay existing 11 meters deep below the surface of the ground.

In order to help monitor this type of problem in the middle of 1936, lectures and work on instrumentation for geotechnical monitoring began, through decades of study and dedication of several researchers. One of the most used and used concepts lately is the use of vibrating rope sensors for the analysis of soil capacity.

Vibrating string instruments are used to determine a frequency for a function of the engineering parameter being monitored, a frequency change is observed when some change in the studied parameter occurs. Vibrating string instruments are widely

recognized for their long-term reliability and durability.

Basically an equipment that employs the technology of vibrating strings, are composed of a steel wire stapled and tensioned, thus it can vibrate in its natural frequency, the variation in the natural frequency occurs with an external stimulus, as well as the hand when touching the guitar. Figure 1 below shows a basic diagram of a vibrating string sensor.

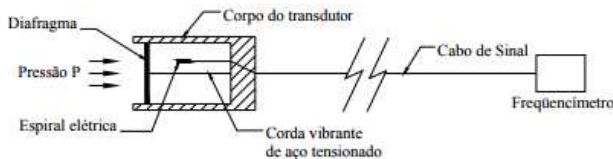


Figure 1. Schematic of the vibrating string sensor (4).

However, the application of sensors for geotechnical or structural monitoring is susceptible to the environment that is being used, so the sensors can work differently depending on the noise level of the environment around them. For example, applications in places with a high level of electricity can interfere in a damaging way in the measurement taken, so depending on the technique used we can subject the sensor to interferences of electrical noise that distort its signal, thus harming the data collection.

In order to analyze vibrating strings sensors for a long time it was necessary to use the Time Domain Analysis Technique technique, this is the most common mode of analysis, and over a long period used as the method of analysis and evaluation of the vibrating string sensors until the emergence of more modern and precise techniques. The most modern sensor evaluation technique is called Spectral Analysis Techniques. (2)

## 2 METHODS OF ANALYSIS

### 2.1 TIME DOMAIN ANALYSIS

Vibrating string sensors can be visualized as a sine wave that oscillates above and below the zero voltage, so whenever the wave crosses the zero we count as a cycle, when we use the

technique of time domain analysis we can verify that in hostile environments like large electrical interference such as, for example, hydroelectric waveform distortion occurs and therefore we observe a change in the measurement taken, this method can not differentiate between the sensor signal and the interference signals (noise), resulting in unreliable data. We must remember that the noise has a diversity of sources and that hardly an installation will be absent from it. In Figure 1 the sensor signal is being modified by the noise, which means that when we analyze the data we will see the sum of the two waves (Resulting Wave). By using the time domain method, there is no way to distinguish the influence and effects of noise on the actual output of the sensor signal, if the noise is relatively small compared to the sensor signal, the interpreted value may be close enough difficult to distinguish between signal and noise.

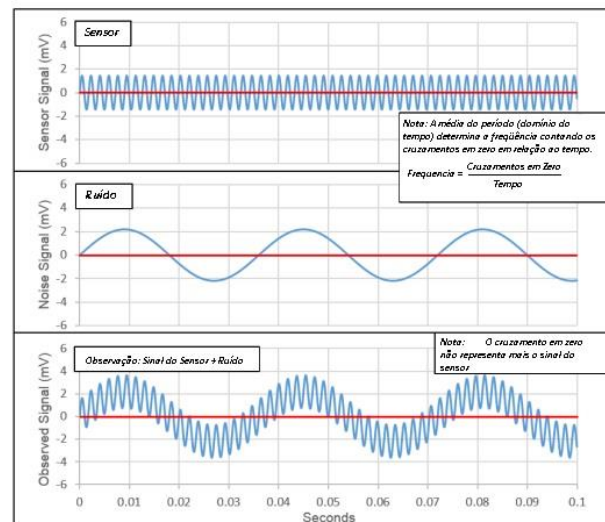


Figure 2. In the first graphic a clean signal, below the combined signal with a simple noise and the final result. In the last chart we noticed that the sum of the noise to the sensor signal generates a false representation of the truly measured signal (2).

### 2.2 SPECTRAL DOMAIN ANALYSIS

Spectral domain analysis uses the Fast Fourier Transform to break it o sinal bruto em componentes de onda individuais, permitindo o noise insulation. Figure 3 demonstrates how the raw signal can be decomposed into an individual wave.

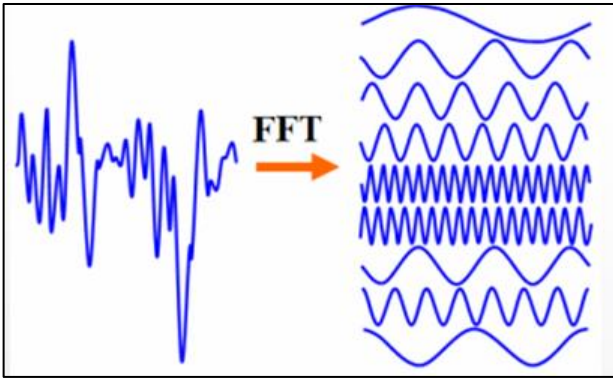


Figure 3. Gross signal with noise decomposed in an individual wave (2).

The steps below basically illustrate how the spectral analysis method eliminates noise without modifying the signal taken in the measurement:

1. The raw signal is recorded (sensor signal and noise signals).
2. A Fourier transform breaks the observed signal into individual sinusoidal components.
3. A spectral analysis traces the various components of the input wave in relation to their individual frequency and amplitude.
4. The largest amplitude signal in the sensor frequency range (defined by the Sensor Model) is interpreted as the sensor signal. (1)

Figure 4 illustrates a graphical representation of a frequency spectral domain analysis of a signal, the steps described above were applied to the Time Domain plot, resulting in the Frequency Domain Chart.

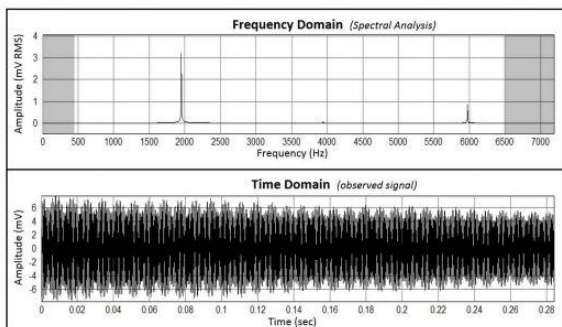


Figure 4. The first graph represents the FFT (Fast Fourier Transform) decomposition of the signal captured from the sensor. The first peak at 1952 Hz / 3.6 mV respectively representing frequency and signal strength. The other two peaks (5973 Hz and 3850 Hz) are the representation of the noises present in the sensor. The

graph below represents the signal of the gross time domain of the sensor, with this graph we tend to confuse the size of the noise value. (2)

### 2.3 VSPECT AND MODES OF IMPLEMENTATION OF TECHNOLOGY

The VSPECT™ provides the best available vibrating strings available. The frequency of the sensor is easily identified while filtering the ambient and electrical noise that affects the quality of the readings.

We know that the resonance frequency is given by the equation below:

$$v = \frac{n}{2l} \sqrt{\frac{\sigma}{\mu}}$$

Where  $v$  is the frequency in cycles in time,  $n$  is a cycle for the fundamental frequency of the vibration mode (non-harmonic),  $l$  is the size of the wire,  $\sigma$  is the strength / area wire tension, and  $\mu$  is the total density of the wire mass / length.

As said before the sensor is constructed so that a wire is held in tension inside a small thin wall tube with small diameter and a structural member, an electromagnetic coil is used to excite the wire and measure the frequency of vibration. The frequency is then used to calculate the number of physical properties of the structural member, typically by applying a series of calibration factors.

In conventional systems, the vibration frequency is calculated by measuring the average vibration period based on the number of times the wave crosses the zero amplitude point over a specified period of time. Although these methods are computationally efficient, they are usually subject to errors because the methods are unable to distinguish between sources of resonance associated with the wire and ao ambiente externo. Assim, fontes de ruído with a small amplitude and a different frequency of the sensor can introduce substantial errors in the measurement taken.

A new approach to checking the measured values determines the resonance frequency of the sensors with the ability to disassociate the

signal noise from the sensor by improving the data acquisition(1).

Thus, in order to implement this data analysis technology more efficiently and accurately, we must have a data collector with VSPECT @ technology in hand, but besides a powerful equipment with a high degree of reliability we must be aware of how to interpret the data acquired.

Figure 5 shows in a simplified way that VSPECT™ technology is used in the data collector and through it we can apply the spectral domain analysis technique and thus differentiate noises from the actual data output.

By analyzing the data we were able to verify the amplitude of the signal and the noise of the sensor, as well as to analyze if the response of the same is adequate and the degree of interference of the signal in the measured value. Therefore we can verify if the sensor response is correct, if the decay rapidly decreases with time, detection of harmonics that can cause small consistent errors that are difficult to detect and difficult to read the sensor, multiple harmonics potential source of noise.

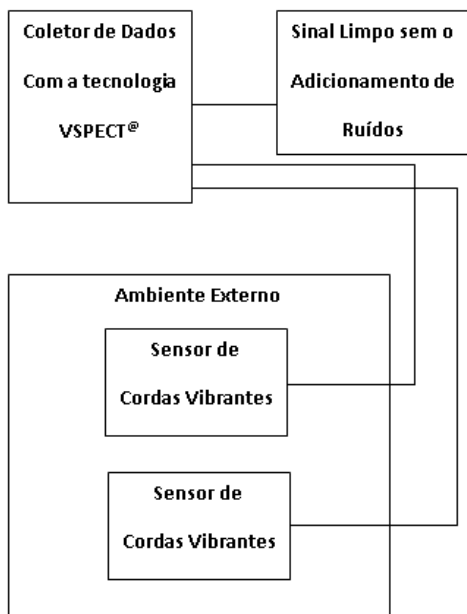


Figure 5. A brief overview of how VSPECT™ technology is applied to data collectors, the main objective is the elimination of noise relevant to the external environment, but in a second function of diagnosing the behavior of the sensor with added noise.

In Figure 6 we verified the diagnosis of a sensor with a possible sensor failure response, it can come from several sources, the time domain graph has an unusual characteristic and there are 60 Hz noises inserted in the sensor.

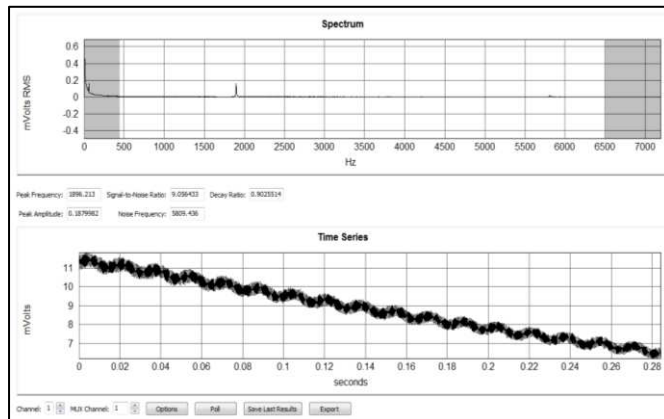


Figure 6. Diagnostics through the VSPECT @ technology of a sensor with several problems, which are able to distort the displayed data and generate incorrect analyzes of the acquired data. (2).

In the above figure it can be verified that possibly the sensor has suffered data in the cable, or faults in the connectors. Possibly it will be necessary to replace it and the laboratory verification of the real reason for the failure, in order to verify possible errors in the preventive maintenance of this sensor.

Thus, using the spectral analysis concept, the peak noise index tends to zero, improving in addition to parameter analysis such as voltage, pressure and deformation.

Helping in the elaboration and verification of a scope for preventive and corrective maintenance of the sensors.

Figure 6 below illustrates how data visualization of an instrumentation and automation is viewed using equipment with VSPECT™ technology.

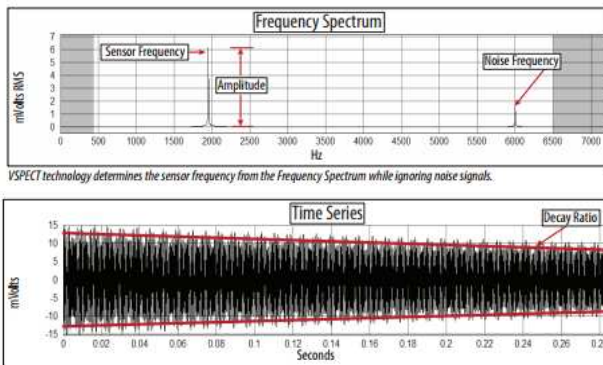


Figure 6. Automated data visualization.

It will be seen from the above figures that automation provides not only the data of the analysis technology in the frequency of time, but also the verification of the data in the time domain. Providing comprehensive tools for the responsible operator to interfere when necessary.

### 3. CONCLUSION

In this work, it is concluded that due to technological progress and faster decision making, it is fundamental and necessary to rely on the data acquired by the sensors applied to the monitoring, so the Spectral Domain Analysis (VSPECT) technology differs of others thanks to its precision and robust data acquisition.

In large facilities there are no time failures, they cause great disasters like inumeros already happened in Brazil and in the World.

So it is extremely necessary to verify the capacity of analysis of your equipment, this will be carried out in the moments of greater tension.

### THANKS

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