Benefits of High Frequency Signal from Process Control Instrument

M Pusayatanont and B. Sookananta

Abstract— *This paper demonstrates the benifit of high frequency signal recovered from sensor signal of process control instrument. Instrument installed in process control system is established for their measurement acuuracy, rangibility and stability. All measurement readings are required in steady state condition and many of them are dc, by the results high frequency fluctuation is removed by signal conditioning especially low pass filter. However this work shown that the high frequecy signal from sensors which always considered as "noise" in conventional measurement techniques contains many useful information of the system such as process fluctuation, disturbance from external source and unpleasant conditionin the system. In order to achieve raw sensor signal, all signal conditioning circuit must be removed and the instrument sensor must have wide bandwidth response and be subjected to signal analysis mainly using the Fourier transform. In this paper, typical process instruments such as pressure transducer, flow meters are investigated. Some selected experimental results are used to demonstrate the potential of the concept for system condition monitoring method without using any additional instrument.*

Keywords— **Process control instrument, Signal analysis, high frequency.**

1. INTRODUCTION

In process industry, there are essential uses of measurement instruments. They give various types of measured quantities corresponding to their in-line processes. In general, the measured values are initially in form of signal, obtained through the sensors. High frequency signal component is filtered out and the DC signal component is retained as finally displayed to users. Remarkably, the discarded high frequency signal contains useful information in condition monitoring [1]. This paper explains a technique to achieve signals from pressure transducer and flowmeter, and clearify the obsecured information in the signal.

For measurement and control reasons, pressure transmitter and flow meter are widely used to measure fluid pressure and flow rates.

There are various types of pressure transmitters as well as flow meters depending on their principles, working conditions and limitations, i.e. some are only suitable for liquid but some are applicable for both liquid and gas, or some may need the different design for different fluids

When measurement installation is completed, system operators or users generally relie on the instrument specification such as standard accuracy, repeatability and stability. They do not have any further information about what is happening in the system, whether the instrument is working correctly or whether it is stop working. They usually keep reading data without warning in case the meter gives incorrect measurement. For example, the dysfunction of differential pressure transmitter can occur when one leg of its impulse lines is blocked. Another example is the dysfunction of turbine flow meter, (typical accuracy < 1%) when it works under flow pulsation . Under this condition, the meter accuracy goes beyond acceptable range. Therefore the user needs warning signal in order to prevent serious problem from incorrect data measurement and on instrument damage.

In common of flow meter measurement principles, a sensor generates signal reflecting on what it is measuring i.e. differential pressure (d/p flow meter), rotating speed (turbine meter), oscillation (vortex meter) or voltage (EM meter) which are in different formats. These signals are converted into electrical form by signal conditioning circuit to bring these signals to appropriate level, smoothed with low noise. Finally they are transformed into the standard forms i.e. 4-20 mA or 0 – 10 V DC for further control procedure or communication.

However, a typical sensor signal has high frequency fluctuation signal embedded in measurement signal which are always treated as "noise" in conventional techniques of measurement. These high frequency fluctuation signals are removed by signal conditioning circuits i.e. low-pass filter in general.

In this paper, the unconditioned sensor signals in high frequency region are extracted from pressure transmitter, Tubine meter, Vortex meter and Electromagnetic meter. The signal is then analysed and the useful information embedding in sensor signal which relates to system condition and instrument working status is revealed and explained.

In order to achieve raw sensor signal, all signal conditioning circuit must be removed and the instrument sensor would have wide bandwidth response.

The analogue raw signal of each instrument which be conditioned to appropriate form is sampled and save digitised data in binary format files and be analysed by signal processing techniques mainly Fast Fourier transform.

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2. BACKGROUND

This section gives brief information about tested instruments.

Pressure transmitter

The electrical pressure transmitter contains three main parts, namely the diaphragm, the sensor and the conditioning circuits. The diaphragm, which provides the interface between the pressure media and the sensor, is usually made stainless steel or some similar alloy. The space between the diaphragm and the sensor is filled with the oil such as silicone oil, olive oil, fluorinated oil, so that the pressure acting on the diaphragm is transferred through the oil onto the sensor. The output signal from sensor can be a change in voltage, capacitance, inductance or frequency, which the conditioning circuits convert to a smooth DC output signal, which can be either a current or a voltage. The conditioning circuit also includes an amplifier and a filter.

The frequency response of each pressure transmitter can be determined by studying the response to the impulse pressure, such as that generated by firing an air gun directly into the pressure port. The impulse responses of two differential pressure transmitters were measured in this way namely the *FOXBORO* Differential Pressure Transmitter model 843 DP-H2I1NS, which has been modified by the removal of the low pass filter in the signal conditioning circuit, and the DRUCK type PT_x 120/2WL Differential Pressure Transmitter. In additions, a Gauge Pressure Transmitter with a range of 2.5 bar from *GEMS SENSOR* series 2000B GA2501A30A, has also been tested.

Turbine meter

Turbine flow meter is a velocity measuring instrument in which the sensor signal is in the frequency domain. When fluid flows through the flow meter, it imparts momentum to the rotor causing it to spin. At constant flow rate, the driving torque generated by the fluid impacting on to the blades exactly balances the resistive drag resulting from bearing, viscous and sensor retarding forces. The rotational speed of the rotor is proportional to the volumetric flow rate of the fluid through the meter and, in the majority of cases, rotation of the rotor is sensed electromagnetically. The signal from the sensor is nearly sinusoidal but is, nevertheless, rich in harmonics due to the slightly differing geometry of individual blades, so that small changes in the radial length and angular spacing of individual blades generate distinctive pulses, but the pattern repeats itself for each revolution of the rotor.

Vortex meter

Vortex flow meter has become established throughout the process industries for the measurement of liquid and gas flows, principally not only because of its wide rangeability, and its linear relationship between frequency and volumetric flow rate, but also because there are no moving parts liable to deteriorate in service. Furthermore, the same *K* factor using for conditioning data applies for both liquid and gases. The most widely used method for detecting the shedding of the vortices involves sensing the change in fluid pressure caused by the transit of vortices past two fixed points immediately downstream of the of the point on the bluff body where they are shed. A differential pressure sensor is widely used but other techniques can be found, such as those in which inductive, capacitance, or strain gauge techniques are used to sense the oscillatory changes in the fluid pressure.

Electromagnetic meter

An electromagnetic flow meter is an electronic, non-intrusive device for measuring velocity of liquids as they flow through a transverse magnetic field. The emf generated between the two electrodes is linearly proportional to liquid velocity based on Faraday's Law. However the liquid must have a conductivity of at least 2 μS/cm. Two basic methods are used to excite magnetic field, AC excitation direct from the mains and pulse DC excitation. However, the zero shift problems and reactive load from exciting coil in AC system are major concern. Therefore, DC pulse excitation is developed. The pulse DC system is used in the majority of systems and it has been refined to provide an accuracy and range-ability which is as good as many or better than other types of flow meters and it has the advantage of a linear output signal.

3. SIGNAL CONDITIONING CIRCUITS

This section presents techniques applied to obtain high frequency signal from each instrument.

Pressure transmitter

The considered signal is obtained from pressure transducer inside the transmitter. The standard output signal of pressure and differential pressure transmitters is a current in the range 4 to 20 mA DC. The current signal has to be converted into a proportional voltage which is done by passing it through a fixed standard 500 Ω resistor. This converts the 4 to 20 mA signal into a voltage form in the range 2 to 10 V DC while pressure signal (in volt) is passed through a 1^{st} order high pass filter to remove DC signal. The filtered signal is AC signal in range of 0.1% or as high as 10% of the typical signal therefore it must be amplified with selected gain into the range 0 to 5 V DC. [2]

Electromagnetic meter

The typical raw sensor signal of an electromagnetic flow meter is very small – in the region of a few microvolts, which is much lower than the random 'noise' and other spurious signals developed at the interface of the electrodes and the flowing liquid. A shielded cable is carefully selected and high gain amplifiers with a very high input impedance are required. Because of very small signal amplitude, the amplifier gain should generally be about 100,000 – 500,000 giving output signals at an appropriate level (±5V). A selected high gain amplifier with a DC blockage - RC network highpass filter, was designed using the popular INA101 instrument amplifier chip. The TL084 JFET- Operational amplifier, which has low input bias current and high typical input resistance are connected as buffer/follower circuits, which provide the high input impedance to the signal source from the flow meter electrodes.[3]

Turbine and vortex meters

The analogue signals from turbine and vortex flow meters are normally in the range 1 to 5 V (ac) at the upper limit of their flow rates which is usually sufficient for the signals to be sampled directly. However, the signal amplitudes are proportional to flow rate and consequently linear amplifiers with a small gain are sometimes required to raise the signals to an appropriate level before inputting them to the signal analysis system.[1],[4]

4. TEST RESULTS

This section explains how abnormal conditions to the meters are applied and the results the experimental studies are given.

Pressure transducer

A FOXBORO differential pressure transmitter model 843DP – H2I1NS, which had been modified to provide the widest possible frequency response by removal of the low pass filter in the signal conditioning circuits is tested by measuring differential pressure across orifice plate. Frequency response in figure 1 demonstrates the high frequency signal especially at 49.25 Hz which is pump speed (rotor speed of motor).

An external oscillator is installed to the line process in order to simulate flow pulsation in the measurement system. The oscillator consists of a bellows attached to the main pipe by a 'T' piece connection and driven by an electromagnet over a range of frequencies by an external oscillator and power amplifier. The result in figure 2 shows that the sensor signal is modulated by external exciting frequency throughout liquid media causing severe fluctuation on the signal as marked in a circle. As a result, the instrument will provide significant error on it reading.

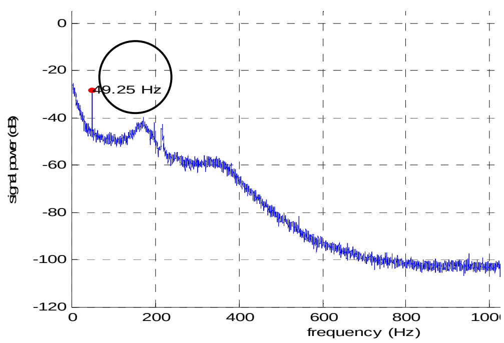

Fig.1. Frequency response of differential pressure transmitter

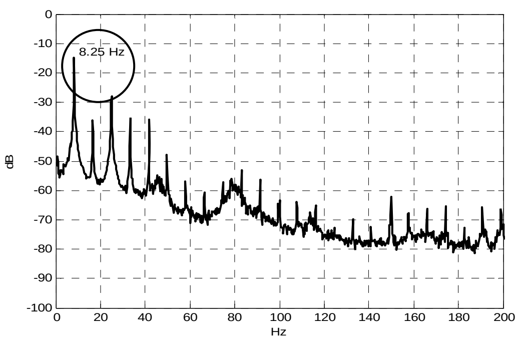

Fig.2. Modulated signal frequency from external source

Electromagnetic meter

The test performed demonstrates that the oscillatory motion in liquid can be detected in electromagnetic flow meter signal. The experiment was set up by a combination of density meter installed in series upstream electromagnetic flow meter. The primary sensor of density meter is a tuning fork. In operation, the tuning fork is immersed in the fluid under test and maintained in oscillation at its resonant frequency by the associated electronic circuits. The reference point is its resonant frequency when located in a vacuum and, thereafter, the resonant frequency is a function of the density of the fluid in which the tuning fork is immersed. The sensor in the density meter oscillates at frequency of about 750 Hz and the oscillation which modulated the flowing fluid, travels through the electromagnetic flow meter where it modulates by ordinary signal of flow meter. The frequency of oscillation can be seen in the spectrum of the density meter signal itself as well as that of the electromagnetic flow meter signal as shown in figure 3.

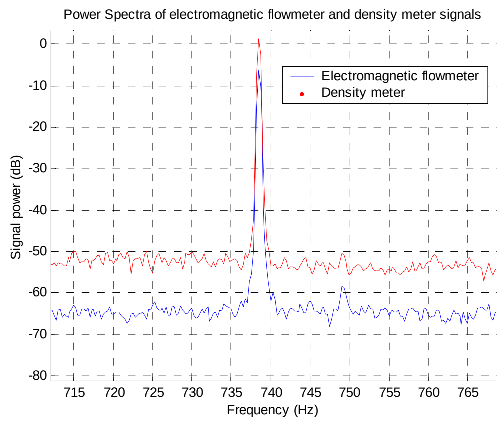

Fig.3. Resonance signal of density meter detected by electromagnetic meter signal

Turbine meter

In many process control system, a control valve is employed to regulate flow rate, and in this instance it also generates turbulence and flow pulsation while it tries to adjust the flow. As the results, the control valve generates high frequency noise strongly effect on the flow meter performance. In the test control caused two distinct peaks on the turbine meter signal which cause large deviation on meter reading as shown in figure 4.

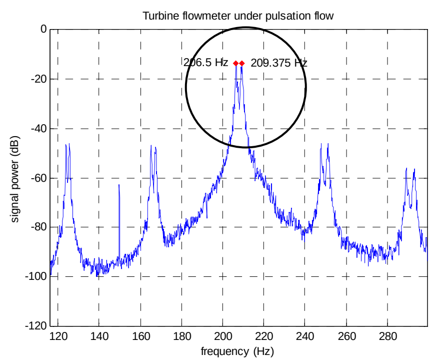

Fig.4 Turbine meter signal with regulating control valve

Vortex meter

A typical vortex sensor signal is shown in the time and frequency domains in Fig.5. When swirling flow, generated by two connected elbows is introduced into the flow, it has a strong influence on the vortex shedding signal in which signal amplitude decreases and vortex shedding frequency becomes unstable.

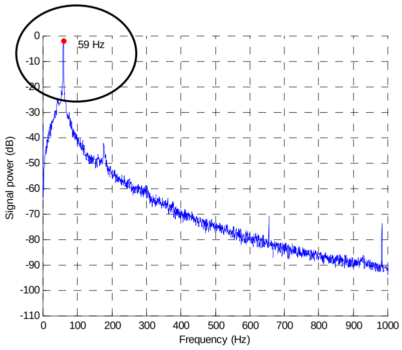

Fig.5 Typical vortex signal

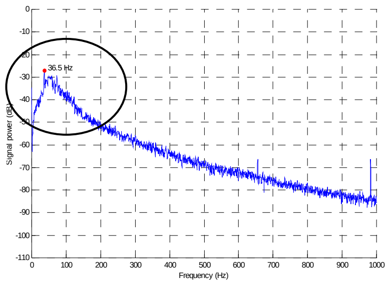

Fig.6. Vortex signal under swirling flow

5. CONCLUSION

This paper presents high frequency signals extracted from measurement instrument in industrial process. These signals give useful information on the process condition and working condition of measuring instrument. As shown in the results, there are irregular signals. They can be detected and further interpreted using signal processing technique. These signals can also be used to warn industrial operators in case unusual conditions occur in the system.

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