Sensor Noise Fault Detection

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Abstract

Current sensor FDIR (fault detection, isolation, & recovery) generally focuses on sensor bias and drift anomalies, which require models. However, dead sensors and excessive noise faults are more common in practice. The latter two faults are interesting in that they can be detected using only the measurements from each sensor. The objective of this paper is to show a few ways to detect common sensor faults and thus, enhance sensor reliability by using instrument signals to better advantage.

Keywords : sensor fault detection, statistical fault detection

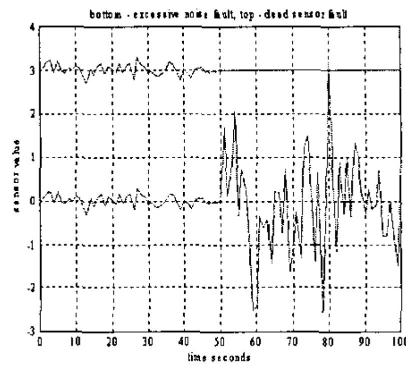
Introduction

Sensor fault detection activity has centered about sensor range checking, analytical redundancy, model-based fault detection, and fault trees. Range checking serves to determine whether instruments are within the nominal operational bandwidth and also saturate data spikes. Analytical redundancy and model-based fault detection are useful for bias and drift fault detection. Fault trees are based on FMEA (failure mode effects analysis) analyses and are used to check for process faults in general. Range checking and fault tree analysis are essential but are limited to the detection of high-level catastrophic events. Much research and applications over the past 3 decades on incipient fault detection have been published[1, 2]. The more subtle, gradual sensor, actuator, or process degradation due to wear, aging, fouling, and/or corrosion that lead up to catastrophic events are generally not detectable in their early stages. Safety or health monitoring is data validation or crosschecking sensor data. This paper is an attempt to present an approach to detect or predict incipient noise or dead sensor faults.

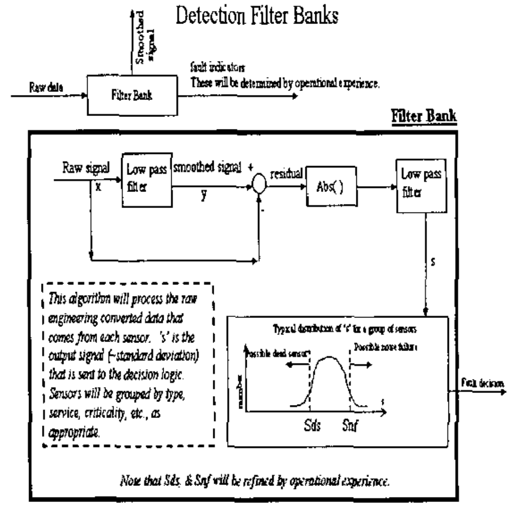
Sensor Safety Monitor

There are 4 types of anomalies from typical analog sensors: dead, excessive noise, drift, & offset sensor faults. Although a multitude of root causes of sensor failures may result in similar measurement signatures, all the information generally available is from the analog signal itself. Therefore, the ability to perform root-cause failure analyses is usually limited. Typical dead and excessive noise faults are shown below. Dead or excessive noise can be detected & isolated using standard deviation of the individual sensor data stream. The standard deviation is compared to the standard deviations of common sensors throughout the plant. A typical way of computing standard deviation in real-time is shown in the accompanying chart. We may take advantage of common sensors in our approach. The standard deviation (SD) of all sensors measuring the same thing should be roughly similar. These SD's may be compared together. Any outliers become candidates for further inspection. In addition, any change of SD of one sensor with respect to its peers or itself should also attract operator attention.

Instrument Fault Types: Excessive Noise & Dead Sensor



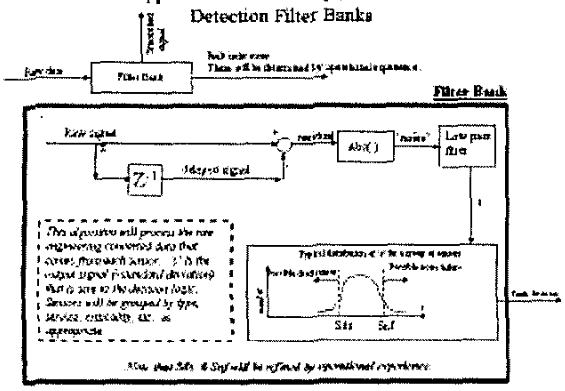
Technical Approach for dead/noisy sensors: Sensor Fault Detection Filter Banks



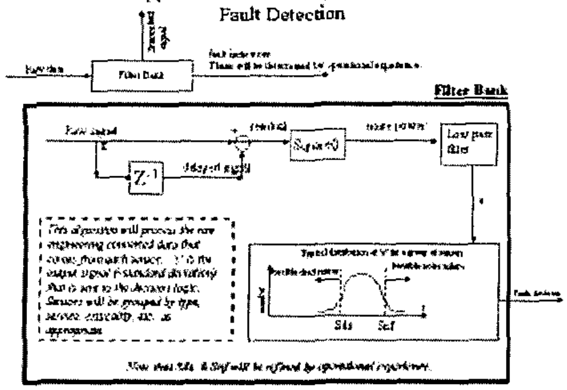
Other approaches can be taken. One is similar to the above and is based on the difference between two successive measurements. This may be considered 'noise'. The absolute value after it is smoothed becomes the indicator signal. The architecture is shown below.

Another approach is to square the above noise and create a noise power. After it is smoothed it may become a noise fault indicator. As the noise power increases beyond a set of thresholds an incipient fault may be indicated. The architecture is below.

Technical Approach for dead/noisy sensors: Sensor Fault Detection Filter Banks



Technical Approach for dead/noisy sensors: Noise Power Fault Detection



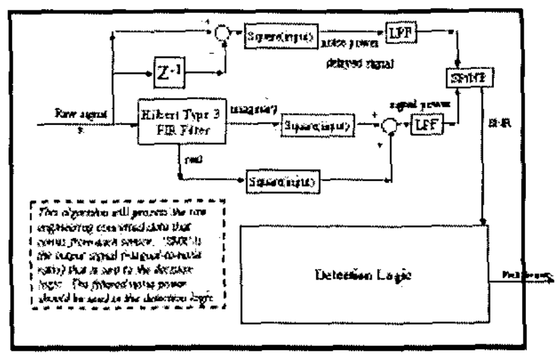
By on-line estimation of the signal power the signal-to-noise ratio (SNR) may be created. One useful approach toward signal power estimation is to use a Hilbert transform[3,4] to generate an inphase (real) component and a quadrature (imaginary) component. A typical equation[3,4] (without windowing) is

$$y[n]=\sum_{n=0}^{M}\frac{2}{\pi}\frac{\sin^{2}[\pi(n-n_d)/2]}{n-n_d}x(n), n_d = M/2,$$

where M is the order, x is the input sequence, and y is the output sequence. Note that the order should be even.

With the inphase and quadrature components determined we can calculate the signal power in real-time. The signal power is the square of the real component added to the square of the imaginary component. The SNR is then the signal power divided by the noise power. The SNR may be used in conjunction with one of the other noise indicators to signal a fault. A typical architecture is shown below. Note that, as shown in the architecture, the real signal part may be extracted from the midpoint of the filter.

Approach for dead/noisy sensors: SNR



Conclusions

A simple approach for on-line monitoring of the sensor systems for noise related faults has been presented. The concepts involve simple computations of SD noise statistics and SNR using only the analog signals themselves. Inexpensive portions of safety monitors for sensors and actuators may be developed.

References:

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