Point Level Capacitance Switch for Fly Ash Hopper Measurement

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If you're the person tasked with controlling the level of fly ash in collection hoppers, you know how difficult the application can be. What at first looks like a simple measurement, quickly proves to be much more demanding in actual execution.

The first problem encountered is the environment inside the collection hoppers. Fly ash is a fine powder that will coat everything inside the hopper. It is a very abrasive material that wears on sensors and finds its way into mechanical devices. Temperatures can be high, reaching in excess of 700°F. The environment inside fly ash hoppers is extremely challenging for most level measurement technologies.

Fly ash is regulated by the U.S. Environmental Protection Agency (EPA) under the Clean Air Act (CAA) of 1970, amended in 1990. The CAA requires facilities burning fossil fuels to capture almost 99% of the fly ash prior to the flue gas being expelled from the stack. Fly ash carries sulfur molecules, which can combine with water if released into the atmosphere. This sulfur was a leading cause of acid rain prior to the CAA regulation's cleanup efforts.

The Fly Ash Removal Process

Fossil fuel burning facilities incorporate a number of pollution controlling processes, but for fly ash the most common methods of removing the ash are by use of an electrostatic precipitator (ESP, Figure 1) or a baghouse.

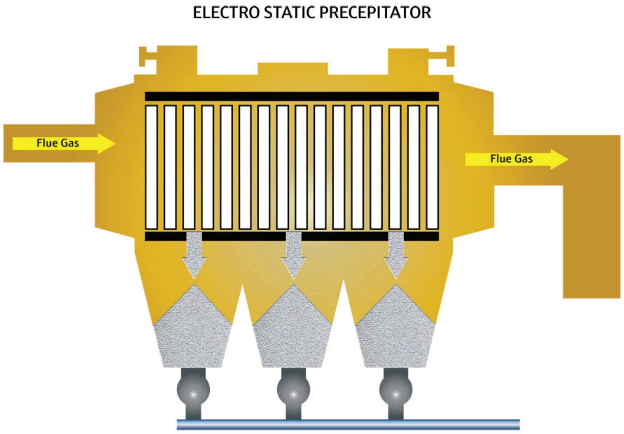

Figure 1: Filtering fly ash. In an electrostatic precipitator, a charged grid attracts ash and particulate matter, and then drops this material into collection hoppers.

The first way is to run the flue gas from the furnace through an ESP. The ESP is a charged grid that creates a static field. The ash and particulate matter in the flue stream statically attach to the grids. “Hammers” on top of the precipitator lift and drop to cause the ash to shake off the grid and fall into the collection hoppers below.

The second approach is to run the flue stream through filters in a baghouse. The filters capture the ash and then are mechanically shaken, or cleaned with pulsing air, causing the ash to fall into the collection hoppers.

Fly ash collected in the hoppers must be evacuated when it reaches a predetermined high-level point. Failure to remove the ash can damage grids and filters, and allow the ash to return to the flue gas stream, resulting in non-compliance with the CAA, and potential EPA penalties.

A point level switch is used to indicate when the ash has reached the high-level point. The ash is then typically removed through a rotary valve in the bottom of the hopper and a vacuum evacuation system.

Reliable Level Detection

There are a number of technologies that are used for the high-point level switch. These include nuclear detectors, paddle wheels, and tilt switches. Some of the technologies work very well, such as nuclear. Other technologies, like mechanical switches, are less dependable. The hot, abrasive, and dusty environment makes switches that rely on moving parts unreliable due to wear and buildup. The sensing technology also must be able to stand up to the extremely hot and abrasive environment inside the fly ash hopper.

A technology that has been used successfully for decades in fly ash hoppers is capacitance. Capacitance switches have no moving parts to wear out. The designs incorporate robust materials for high-temperature service, reducing maintenance and increasing reliability.

A capacitor is made up of two conductive plates separated by a non-conductive dielectric material (Figure 2). Dielectric materials are categorized by their dielectric constant (DK), which is a number that is related to the material’s ability to store a capacitive charge. The higher the dielectric number, the more capacitance it can store.

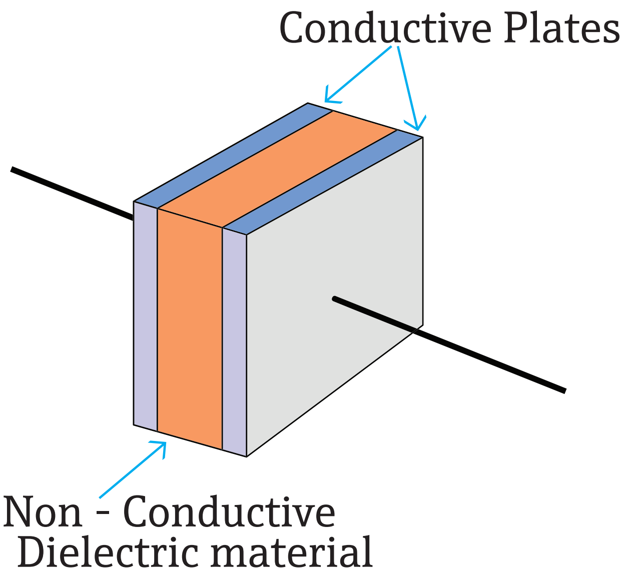

Figure 2: The concept. Two conductive plates separated by a non-conductive dielectric material form a capacitor.

Capacitance technology for level measurement uses this same basic concept. In the case of a point level measurement, the hopper becomes a variable capacitor. The sensing element becomes one conductive plate, the hopper becomes the second conductive plate, and the material being measured is the dielectric.

The formula for capacitance is:

C = DK x A / D

where:

C is the capacitance,
DK is the dielectric constant (Note: the dielectric material in a fly ash hopper is the fly ash itself),
A is the area of the active portion of the sensing element,
D is the distance between the active sensing element and ground (the hopper wall).

Figure 3 shows the sensing element in a hopper in an uncovered condition. In this case, the dielectric material between the two plates of the capacitor is air. During the calibration process, capacitance generated by the sensor in air is balanced out. Further, an additional amount of capacitance is added to make the switch more stable. This additional amount of capacitance is called the switch point. The larger the switch point, the more stable the switch will be.

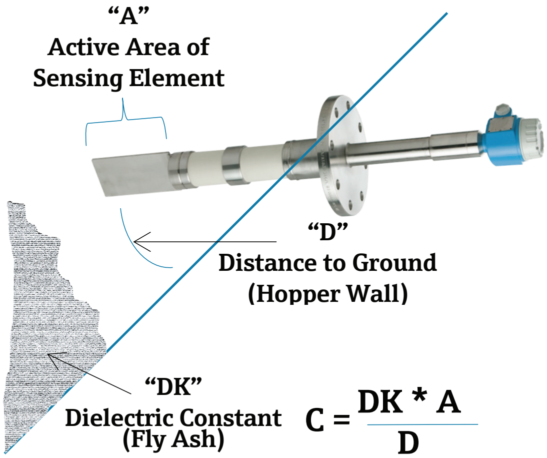

Figure 3: A low-level scenario. The detected capacitance is less when no fly ash is present.

Figure 4 shows the sensing element covered with the dielectric material (fly ash). As the fly ash covers the active portion of the sensing element, it displaces the lower dielectric material (air) between the plates of the capacitor. This change from lower to higher dielectric material between the plates causes the capacitance to increase. The output of the point level switch changes from the uncovered to the covered state when the increasing capacitance exceeds the switch point.

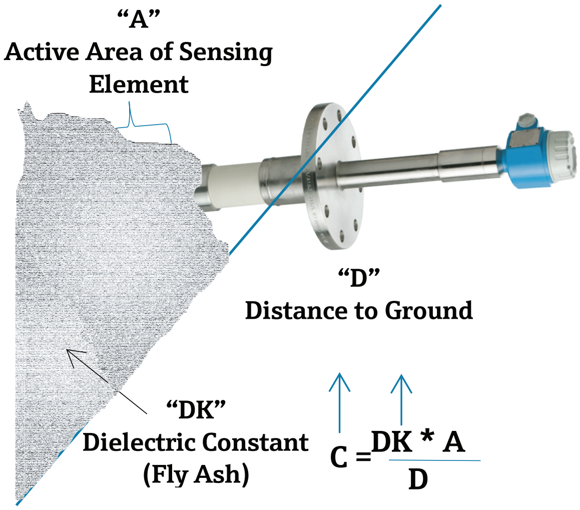

Figure 4: A high-level scenario. The detected capacitance increases as fly ash covers the active area of the sensing element.

Improving Stability

The key to using capacitance technology for point level measurement is maximizing the amount of capacitance generated. The reason for this is that by generating more capacitance we can make the switch less sensitive and, therefore, more stable and reliable.

Increasing the active area (A) of the sensing element by making the active plate larger, results in more capacitance being generated (that is, DK x A will be greater). With a larger active area, we can set a larger switch point. In other words, we have a larger dead band, as the difference in the capacitance value between the uncovered and covered conditions is much greater.

This is important because the capacitance point level switch is like a balance bridge. On one side of the bridge is the sensing element in the hopper. On the other side of the bridge is a tuning adjustment. There are two balance bridges shown in Figure 5. The switch point adjustment with the smaller active area, can only add a small switch point. However, by increasing the active area of the sensing element, a larger switch point adjustment can be used making the switch more stable.

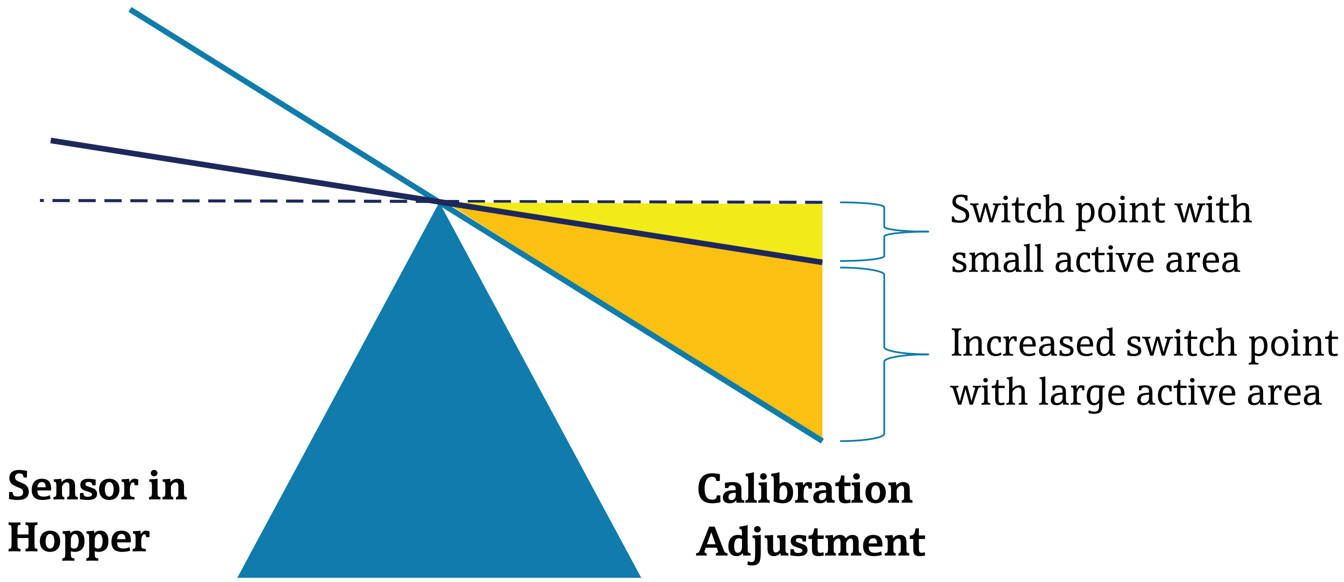

Figure 5: A balancing act. A larger sensing area makes the capacitance switch more stable.

Stability in a capacitance switch is everything. An unstable switch will have false trips due to coating and environmental changes inside the hopper. Anything that affects the sensing element side of the switch, such as coatings, will increase the capacitance on that side of the bridge. If the increase exceeds the switch point, the switch will show a covered state, or false trip.

Poor detector performance can result in costly repairs, as one Midwest power-generating company learned. It had been using capacitance point level switches to indicate a high level of fly ash in their collection hoppers. The capacitance sensing elements were the traditional rod style with a small active area, providing a relatively small amount of capacitance change between the uncovered and covered state. Because of the small delta, the switches were calibrated to a very sensitive setting. As a result, the switches provided false trip indications regularly. The operators did not trust the switches and ignored them, resulting in maintenance and repair costs of $80,000 over several years of operation.

The faulty capacitance switches were replaced with capacitance switches with a large active plate. The large active area provided a greater delta change in capacitance between the uncovered and covered state, which allowed the calibration to be less sensitive and therefore more stable. The new switches have been in place since 2010 providing reliable high-level indication. The operators now rely on the high-level indication to evacuate the fly ash from the hoppers. The robust construction and high-temperature design ensure a long, maintenance free life.

Consider Your Options

There are many capacitance switches available in the market designed with small rod type active areas. The smaller the active area, the less stable the switch will be. The reduced stability results in false trips and questionable reliability.

It is also important to consider the construction of the sensing technology used in the fly ash hopper. Fly ash is a very abrasive material and will coat everything inside the hopper. The temperature in some hoppers can be in excess of 700°F. Technologies that employ moving parts, such as paddle wheels or tilt switches, do not survive for long in this extreme environment. Capacitance sensing elements with robust designs, high-temperature insulators, and active build-up compensation to offset for coatings are well suited for this environment. Most importantly, maximizing the active area of the sensing element (Figure 6) to increase stability is the best way to ensure a successful application.

Figure 6: Larger is better. A capacitance-sensing element with a large active plate maximizes the capacitance charge.

When looking at level switch technologies to measure fly ash hopper levels, it is important to understand how the technologies operate. Knowing that capacitance point level switches are a good choice for this application is not enough. There are many manufacturers of capacitance point level switches to choose from. Very few of these manufacturers offer sensing elements designed to maximize the stability of the switch. Sensing elements with large active areas provide stability and reliability, and are worth considering for capacitance fly ash measurement.

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