Bin Level Indication Applications in Coal-Fired Power Plants

Introduction (Wikipedia)

A coal fired power plant is one of three possible fossil fuel type plants. At the turn of the current century coal fired power generation accounted for more than 50% of the electricity generated in the USA. Other fossil fuels include oil and natural gas. Coal and oil are not considered clean burning fuels, though new methods have been developed to clean burn even coal.

A coal fired plant converts coal into thermal energy, and then finally into electricity. The process to do this can be represented in the diagram in Figure 1. Coal processing and

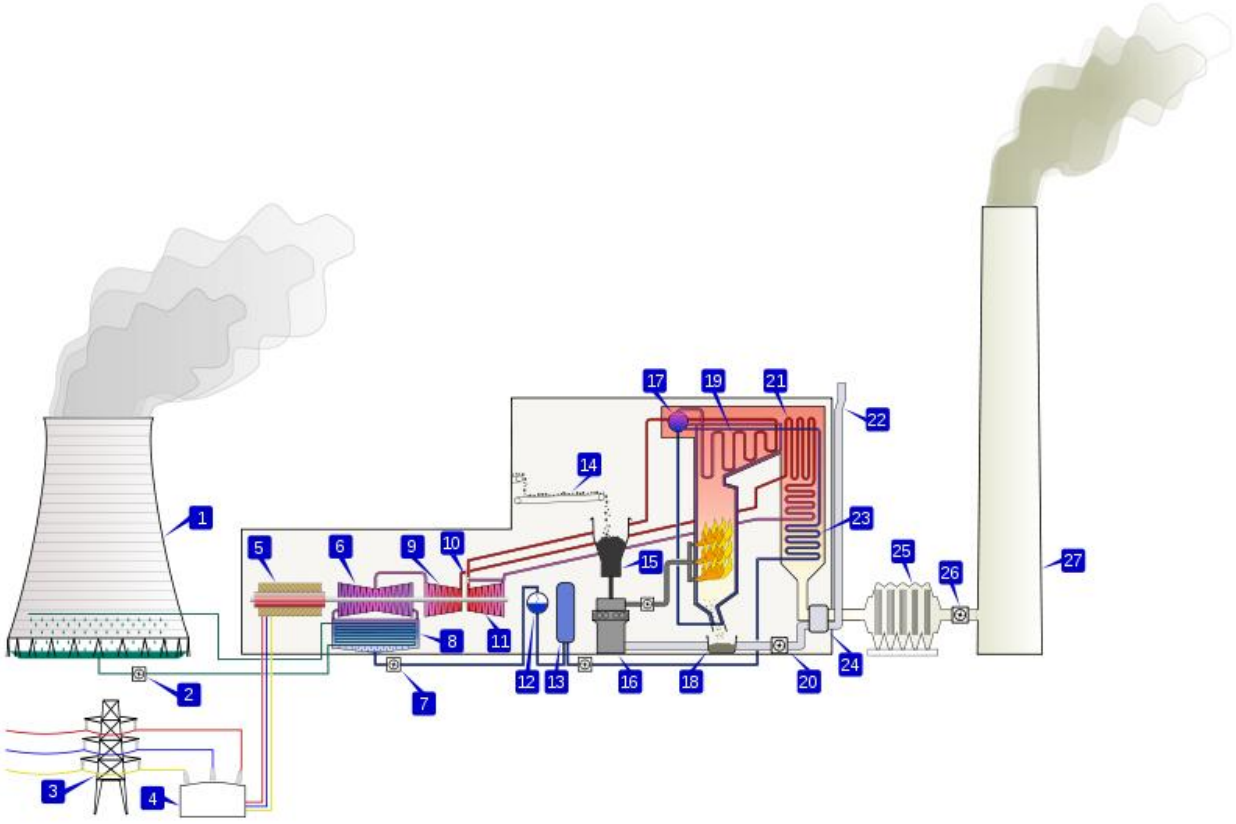

Figure 1: Coal Power Generation Diagram

handling within this diagram is found in items 14 and 15, the coal conveyor (14) and the coal hopper (15). However the process where level measurement and monitoring occurs can be better seen in Figure 2.

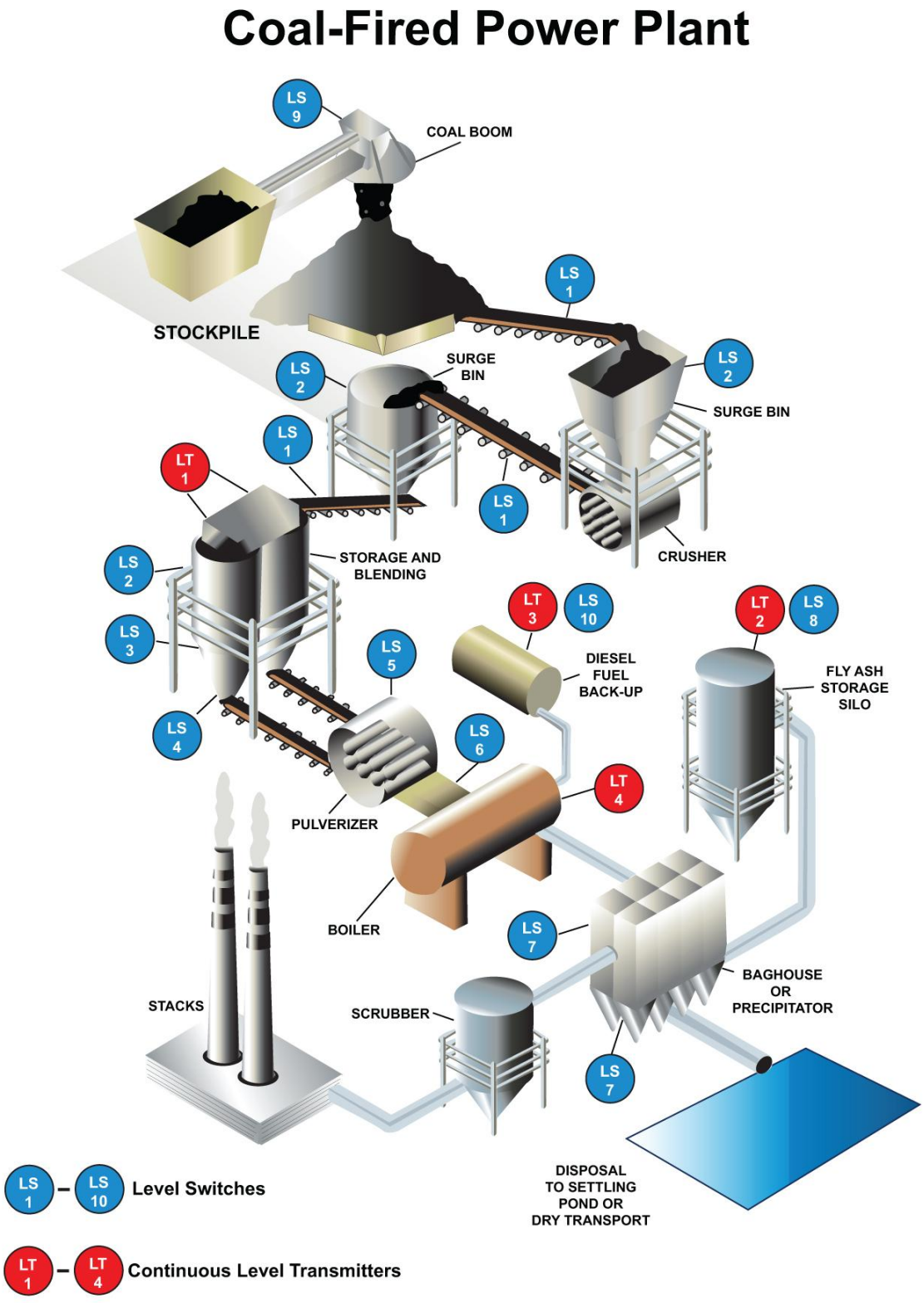

Figure 2: Level Sensing Process Diagram for Coal-Fired Power Plant

Let's review each potential application by number, but first let's distinguish between point (level switch) and continuous (level transmitter) level monitoring.

Point level monitoring is the detection of presence and/or absence of material within a bin, hopper, silo et al at a predetermined point. The material is either present or is absent and the level sensor takes an action with its output accordingly. Point level sensors are typically used to indicate either a high level or low level condition. They are used to prevent bin overfilling and indicate near or at material outage. They can also be used to indicate proper material loading on mechanical belt conveyors.

Continuous level monitoring uses a sensor that addresses the question "how much stuff do I have?". This device will emit an output that is "continuously" changing to reflect the level within the bin, hopper, tank, silo et al as it fluctuates on a periodic basis. Continuous level sensors are used for both process control and inventory monitoring and management.

The most typical point level sensors include *Rotary Paddle*, *Tilt Switch*, *RF Admittance* and *Vibrating Element* devices. The most common for continuous level are *Through Air Radar*, *Guided Wave Radar (TDR)*, *Ultrasonic* and *Glass Gages* (boiler only). A brief description of the operation of each type of device is found below.

Rotary Paddle (Point): This sensor is for use in detection powders and granular materials only. A synchronous motor inside the instrument enclosure rotates a single or multi-blade paddle that is located inside the bin at 1 rpm. When material is surrounding the paddle the rotation stops and this is detected within the sensor. A switch or relay output indicates either presence or absence. These are used for both high and low point level sensing, as well as plugged chute detection.

Tilt Switch (Point): A Tilt Switch is a level detection device that is used primarily only for high level sensing and also for conveyor belt load detection. The sensor is suspended over a pile of material (in silo, under conveyor or over material load on belt conveyor). The material height will contact the tilt sensor and tilt it by 15-17 degrees at which time a switch closure will occur indicating that material is present. When the material pile falls away where the pile no longer tilts the sensor, the switch output reverts to its previous state.

RF Admittance (Point): This level detector uses a radio frequency signal and monitors the change in RF admittance to indicate either the presence or absence of material. The admittance change from its calibrated state is affected by the dielectric of the material being sensed. This technology eliminates the moving parts of both Rotary and Tilt Switches, however, there are more application limitations with RF Admittance than with Rotary and Tilt switches, which also tend to be reliable lower cost devices.

Vibrating Element (rod or fork): Vibrating element level sensors primarily use piezoquartz crystals that vibrate a rod or fork element at a natural resonant frequency in free air. As material comes in contact with the sensor element the vibration is dampened and changed. The electronics sense this vibrating frequency change and interpret it as sensing material presence. These level sensors provide relay output and can be used for both high and low level, but are typically excluded from conveyor belt load detection. They are especially useful for dust collector backup protection where you are looking to detect a high level condition of dust collected in the hopper of dust collector systems.

Weight & Cable (Continuous): A weight & cable sensor is used primarily for inventory management purposes, not for process control. These sensors measure the distance of empty space and infer level based on the height of the vessel. The time between measurements is often user set but is typically every several minutes to periodic once or a few times per day. They are used for material levels that are not rapidly changing, even during filling. They can provide analog 4-20mA and digital communications output.

Ultrasonic (Continuous): This device generates an ultrasonic pulse and measures the time-of-flight of the pulses from the time they are generated and their reflected energy received back at the transmitter. The time is directly related to empty space distance based on the speed of sound through the internal vessel atmosphere, usually assumed to be that of air. These units can be fairly reliable for liquid level measurement applications but are more problematic for powders and granular materials, powders especially, and we suggest they be avoided in those applications.

Through-Air Radar: Typically using FMCW (frequency modulated continuous wave) or Pulse radar technologies, these devices measure empty space distance by measuring the time-of-flight of radar energy from when it is emitted to when reflected energy is received back, however, the FMCW use a frequency change measurement to determine distance. Wikipedia provides further definition of FMCW and this can be found at http://en.wikipedia.org/wiki/Fm-cw_radar.

Guided Wave or TDR (time domain reflectometry): Most all guided wave radar units use TDR technology which measures the time-of-flight of radar pulses traveling (guided) to the material surface along a waveguide (usually a heavy duty cable or rod) and their reflection off the material surface. These units are fairly reliable in both liquid and powder bulk solid applications. However, low dielectric constant materials with Er = 1.8 and less can be problematic if the distance to be measured exceeds 20-30ft. The time is related to the distance of empty space.

Typical Point Level Applications – Coal Fired Power Generating Stations

(LS-1) Conveyor Belt Loading (over/under detection): Coal is transported to, from and within process points using belt conveyors. These conveyors can be very long and are also used in the mining and aggregate processing industries. Detecting the level of loading at some maximum/minimum level aids in making sure coal is continuously present at a typical amount on the moving conveyors. This is a high level detection application of the material on the conveyor belt.

A lack of coal might be caused by a blockage or defective process equipment upstream. This can be detrimental to efficient operation of the plant and also lead to a dangerous condition if not quickly detected.

The most typical point level device used for this application is the Tilt Switch. It is reliable, rugged and relatively low in cost.

(LS-2) High Level Alarms for Silos, Bins and Hoppers: This is one of the most common uses of point level sensors/switches. High level. The devices used for this type of application have two primary purposes. First, provide an alarm to indicate the bin or silo is full. Second, is to prevent overfilling by being a sensor which in some manner is interlocked with the bin filling system.

By preventing overfilling these inexpensive devices save thousands of dollars in costs associated with lost material, clean-up, equipment damage and in some cases even regulatory fines. By providing indication of a full vessel, they aid in the process control and plant efficiency.

The most typical bin level sensors used for high level detection in silos, bins and hoppers are Rotary Paddle and RF Admittance. Vibrating element sensors may also be used but these sensors are somewhat sensitive to bending due to shifting load of material in the bin and this should be considered.

(LS-3) Low Level Alarm: A low level sensor is typically used to indicate a material outage condition is near or exists and it warns or provides a process control input to indicate required action in order to maintain continuous process flow. It also could indicate a potentially dangerous process condition if fuel to a boiler system were cutoff because of a material outage in a bin or tank. In many cases these sensors are located at a point to indicate material re-ordering is required. But with a continuous flow of coal to the pulverizer being required to maintain continuous operation, it is more commonly used to indicate a serious material outage or slowdown condition.

Low level detection of coal requires rugged sensors including the use of Rotary Paddle and RF Admittance type point level sensors. Vibrating element sensors are sensitive to having their probes bent, even so slightly that you cannot see it with the naked eye. Therefore, low level applications for Vibrating Element sensors require care in installation and should be used with materials typically 45lbs/ft^3 or less.

(LS-4 and LS-6) Plugged Chute Detection: When coal plugs in a chute it backs up and starves the downstream process. It can interrupt the continuous flow of the process, cause a spill of material and even create a hazardous condition as gases build up and downstream equipment continue to try to operate in a starved condition. Anywhere the coal flows through a chute, this condition can potentially exist and requires detection.

Point level sensors have long been used as plugged chute detectors. They detect a positive presence of material, rather than a flow of material. The level sensor cannot be located in the flow stream, however, as it may indicate a false positive for a plugged condition. The chutes can be fabricated with a side-out where the level sensor can be mounted. Presence of material in the side-out area can only occur during a plugged condition.

In some applications, monitoring the flow of pulverized coal from the pulverizer to the burner at the boiler is done using a solid-state flow sensor based on microwave technology. This sensor can provide a positive indication of flow/no-flow to the process control system.

Point level sensors typically chosen for plugged chute detection include the Rotary Paddle and a flush mounted RF Admittance sensor. The flush mounted sensor can be mounted in the wall of the chute without a side-out. As an alternative, a low cost electromechanical diaphragm pressure-sensitive switch can also be used in some situations.

(LS-5) High Level on Pulverizer Mill: The amount of coal flow into and through the pulverizer is closely managed by the operator or process control system in order to maintain highly consistent operation of thermal energy to the boiler and thereby producing consistent steam generation and electricity production. The high level sensor assists in that process. This point level sensor will indicate when a high level condition exists which can indicate too much overall feed of coal to the pulverizer or a blockage or partial blockage of pulverized coal being feed to the burner.

Rotary Paddle and RF Admittance point level sensors offer the most reliable operation in this application.

(LS-7 and LS-8) Fly Ash High and Low Level: Dust collectors using filter bags or Electrostatic Precipitators (ESP's) are used to remove ash or particulate matter from the hot stack gases produced by the combustion of the coal. The ash must be removed from the bottom hoppers of these dust collection systems before it can clog the collector and damage the equipment and bags.

The most typical application in the ESP or dust collector is to detect a high level condition within the collection hopper to prevent damage and clogging. In addition, high and low level sensing is implemented in the fly-ash storage silos to indicate material outage (low) and prevent overfilling (high). Fly-ash is a by-product of the coal combustion process that used to go to dump sites. However, due to increasing EPA restrictions, fly-ash has found many other productive uses, including as an ingredient to concrete and cement production. Therefore, most all coal-fired power generating stations produce fly-ash that is sold either to a fly-ash processor or directly to users of the fly-ash.

The most common point level sensors used for fly-ash detection include the Rotary Paddle, RF Admittance and Vibrating Element sensors. Vibrating Element sensors may be especially helpful for high level detection in silos as the ash is often pneumatically conveyed and very light at the top of the pile. The high sensitivity of some vibrating element sensors may come in handy. However, Rotary Paddle and RF Admittance are applicable, especially in high temperature applications at the ESP. Rotary Paddle units can be obtained for use at as high as 750°F, and some even over 1000°F. Split-architecture RF Admittance sensors with ceramic insulators can be used at up to over 1000° F as well. High temperature Vibrating Element sensors are much more limited.

(LS-9) High Level for Boom Control: Controlling the position of the coal boom is required in order to create multiple piles of coal. Each pile is a height that is just under the coal boom. As the conveyor of the coal boom deposits material on the ground a pile develops and increases until the high level sensor tells the control system that the high level point is reached and the coal boom should be repositioned to another location and a new pile of coal is started.

The most typical level sensor for this application is the use of a Tilt Switch suspended from just beneath the coal boom conveyor. The Tilt Switch is a very simple and reliable device in these applications and used for just high level detection. RF Admittance and Vibrating Element sensors may also be used but the most common sensor for conveyor control in this manner is a Tilt Switch.

(LS-10) High Level Alarm for Diesel Fuel: Most fuel tanks will incorporate a continuous level transmitter without a high level indicator. However, when a high level alarm independent of the continuous level transmitter is required, an RF Admittance, Ultrasonic Gap or Vibrating Element tuning fork are the most common and all are available in HazLoc designs.

Typical Continuous Level Applications – Coal Fired Power Generating Stations

(LT-1) Coal Storage/Blending Continuous Level: The storage and blending of different types of coals allow the power generating station to feed its boilers with a blend of coal that will produce a consistent Btu output. Coal storage and blending silos have their inventory levels continuously monitored to ensure an adequate supply level and good process control. Typically low Btu coal (lower cost) is blended with high Btu coal to produce a constant output power level.

The continuous level transmitters chosen for these applications must be mechanically robust and very reliable. Through-Air Radar, Ultrasonic and even Weight & Cable systems are all used to make these continuous level measurements. However, the continuous nature of the Radar and Ultrasonic level sensors makes them preferred. While Weight & Cable devices can be operated on a continuous duty cycle, this reduces their motor life and may cause premature failure.

(LT-2) Continuous Level Fly-Ash Silos: Fly ash storage silos are used to inventory the fly ash from the dust collection / ESP system for transport to a fly ash processing or usage facility. These silos are very large and hold hundreds of thousands of pounds of ash. Because the ash is very dusty and the conveying system is pneumatic, a large amount of airborne dust is created inside the silo environment. These dust clouds are so severe that they can “blind” the Through-Air Radar and Ultrasonic technologies.

The most common inventory monitoring sensors used for this application is Weight & Cable and Guided Wave Radar (TDR). The slow changing levels make the periodic nature of Weight & Cable devices viable and the guided wave approach to the TDR radar works very well, even given a relatively low dielectric constant. Most fly ash silos are up to 60 feet in height.

With TDR, a single heavy duty cable design is a must. In addition, the sensor must be able to measure the continuous height with a material dielectric constant that could be as low as 1.6-1.8 depending on the type of coal that is burned. Not all TDR are created equal. However, most popular brands of Weight & cable will work equally well.

(LT-3) Diesel Fuel Level: Diesel fuel is used as a backup to the coal source for combustion in the burner to keep the boiler going and the power station operating should the coal supply stop for any reason. This level transmitter provides a continuous indication of the amount of diesel fuel on-hand.

The typical level transmitter technology used for fuel tanks can range from Magnetostrictive, RF Admittance, Magnetic Liquid Level to Hydrostatic.

(LT-4) Feed Water Heater Level: Feed water level in the boiler is a critical parameter that must be controlled. The level transmitter provides a reliable indication of the amount of water in the boiler to aid in the removal and distribution of heat and make sure that water is not lost and that a boiler burnout does not occur.

The level transmitter technology in this application may be controlled by ASME pressure vessel code. Consult these standards. However, a magnetic liquid level transmitter is a great solution should it meet or be combined with a glass gauge that meets the code.

Conclusion

Point and continuous level sensors are an integral part of the operation of a coal fired power generating station. Not one technology will fit all applications, in fact, several will be needed to optimize sensing and operation. Rotary Paddle, Tilt Switch, RF Admittance, Vibrating Element, Radar, Sonic, Weight & Cable, Magnetic Liquid Level Gauge. All have their fit within the typical coal fired power plant.