Neural Network Flame Detection Technology for Reliable Monitoring

By Shankar Baliga

Accurate flame monitoring is a safety, process, and risk management challenge for chemical plant engineers. Chemical plant operators need reliable flame detection for flash fire conditions that spread rapidly and cause great harm. They must at the same time minimize the potential for false alarms that initiate fire suppression systems unnecessarily, cause damage to equipment, and impede productivity.

False Alarms

Insufficient differentiation of actual flames from ambient plant background sources causes highly undesirable false alarm conditions. Until recently, state-of-the-art optical flame detection was based on multi-spectral detection integrated with an expert signal processing system. This expert system is based on a fixed set of conditions derived from the spectral analysis of a selected group of wavelengths and programmed into computer logic. This technology has been prone to false alarms when exposed to reflected light, hot piping, movement of human operators, machinery, and others.
The five optical flame sensing technologies most commonly in use are listed below:

&#149 Ultraviolet
&#149 Ultraviolet/infrared
&#149 Dual infrared
&#149 Triple infrared
&#149 IR/Closed-Circuit Television

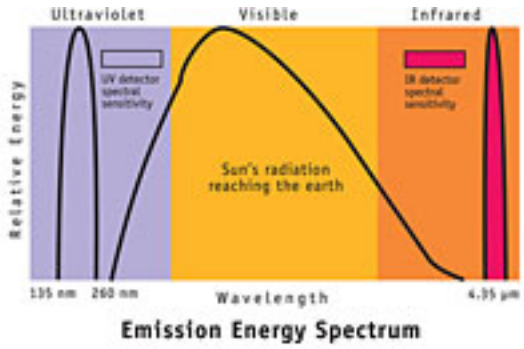

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Figure 1 (Click image for larger version.)

All five technologies are based on line-of-sight detection of radiation emitted in the UV and IR spectral bands by flames as shown in Figure 1. Chemical plant operators typically select one of these technologies after considering their plant's requirements for detection range, field of view (FOV), response time, and false alarm immunity to various sources.

More on UV Technology

Ultraviolet (UV) technology is specified for its ability to operate at relatively high speed with good sensitivity up to 50 feet from the flame. UV detectors are unaffected by sunlight and hot objects and are a low-cost solution compared to other detectors. Limitations include vulnerability to false alarms triggered by other UV sources such as halogen lamps and electrical sparks. Thick smoke and/or grease accumulation on sensor windows can cause failure to detect flames.

Ultraviolet/Infrared

Integrating a UV optical sensor with an IR sensor produces a dual-band detector that is sensitive to both UV and IR radiation from a flame but offers increased immunity over a UV detector. When combined with flicker discrimination circuitry, it reduces the possibility of false alarms caused by lightning, sunlight, and hot objects. Ultraviolet/infrared (UV/IR) detectors operate at moderate speed at up to 50 feet from the flame. While the cost is moderate compared to other detectors, UV/IR detectors are impacted by thick smoke and grease deposits on the detector window.

IR2 and IR3

Dual and triple IR flame detectors use multiple infrared spectral regions to improve differentiation of flame sources from non-flame background radiation. These types of IR detectors work in locations where combustion causes extremely smoky fires. They operate at moderate speed with a range of up to 200 feet from the flame. These instruments exhibit relatively high immunity to infrared radiation produced by lightning, sunlight, and other hot objects. However, their cost is high relative to other devices.

CCTV/IR3 Technology

IR/Closed-Circuit Television, CCTV/IR3, flame detectors combine three IR sensors covering multiple areas with video cameras. These devices have the same benefits as IR3 detectors and include viewing capabilities. Video lets operators monitor areas remotely for fire and investigate alarms so that the best response can be determined before taking action. Their cost is higher compared to other flame detectors. While they provide a detection range of 200 feet from the flame, the video camera coverage is typically less than the full infrared detection range. The operating temperature range for the video camera is narrower than for the IR3 detector array.

Selection Criteria

Following is a brief overview of five key flame detector performance criteria and considerations for solution selection.
&#149 *False Alarm Immunity*
False alarms are more than a nuisance. They are both a productivity and cost issue. False alarm incidents in most chemical processing plants require a system shutdown, probable evacuation, and investigation. Turning off and re-starting a process line is time-consuming, impacts complex material batching or quality requirements, and can affect environmental regulatory reporting.
&#149 *Detection Range and Response Time*
Depending on a specific plant application, each alternative flame detection

technology will recognize a flame to a maximum distance. Operators are seeking a given flame sensing device that requires the shortest time to detect a flame over the greatest distance.

&#149 *Field of View*

The most common types of optical flame detectors have a 90- to 120-degree field of view. A wider field of view can limit the maximum detection distance. Therefore, it is often necessary to place optical flame detectors with overlapping coverage to achieve the required coverage.

&#149 *Operating Temperature Range*

In today's rigorous chemical processing and petrochemical plants, optical flame detectors need to operate over a wide temperature range. In addition to extreme temperatures, flame detectors must support explosion-proof requirements and other rugged environment needs.

&#149 *Communication Capabilities*

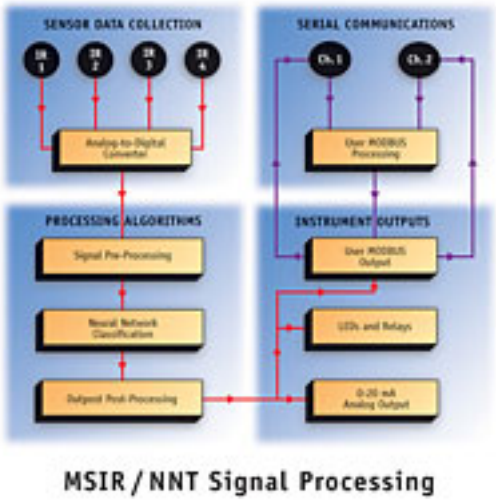
Flame detectors must be able to communicate effectively. At a minimum, a 0-20 mA analog output is required for remote alarm and fault indication. A RS-485 serial communication link with MODBUS RTU compatibility to network multiple detectors in larger areas is mandatory.

New False Alarm Solution

Figure 2

The development of Neural Network Technology (NNT) for multi-spectral optical flame detectors helps to resolve the problem of false alarms within chemical plants and other hazardous environments. NNT flame detectors are based on artificial neural networks (ANNs), which have become a proven design technology in use for over a decade. ANNs are mathematical models of biological neurons in the human brain that can correlate given signal patterns with target flame conditions identified with a multi-spectral optical flame sensor.

The multi-spectral IR (MSIR) optical sensor array and the neural network function together as an adaptive and intuitive decision-making mechanism with exceptional optimization capability as a flame detector. The result is breakthrough flame detection that provides the industry's most reliable discrimination between actual flames and nuisance false alarm sources. NNT's application to flame detection systems is now helping reduce operating costs by providing superior performance and reliable flame detection to protect lives.



[2]

Figure 3 (Click image for larger version.)

The advanced FL4000 Flame Detector (Figure 2) combines MSIR optical sensing and NNT technologies. This flame detector's MSIR optical sensor array samples different IR spectral areas to detect a flame. Each sensor's analog signal is sampled and then converted into digital format for initial signal pre-processing to extract time and frequency information as depicted in Figure 3. The time and frequency information are used by the flame detector's sophisticated NNT classification algorithm to identify if input IR signals are emitted from a flame or non-flame source. The flame or non-flame decision is then reported as an output via LEDs, relays, and MODBUS to the control system.

NNT Advantages

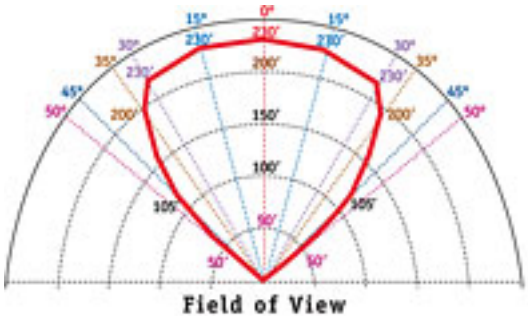


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Figure 4 (Click image for larger version.)

Combining MSIR optical sensing with the NNT flame discrimination algorithm offers several advantages to process engineers. False alarms are greatly reduced from arc welding, reflective surfaces such as tanks, and machinery movement. As shown in Figure 4, the detection range is also extended with MSIR/NNT technology up to 210 feet with a wide FOV of 90 degrees, offering the potential to reduce the number of detectors required to protect a plant.

In conclusion, the application of MSIR/NNT technology to flame detectors represents a next-generation solution that improves safety, reliability, and operations with the potential to reduce costs and long-term maintenance.

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