Substations

Design Guide

January, 2010
Doc 11737_00

Preface

Xtralis has produced this Design Guide as a reference, to be consulted when designing VESDA fire protection solutions for various types of Substation facilities.

This Design Guide outlines relevant design considerations and makes recommendations regarding the most effective way to implement a VESDA system solution in Substation facilities.

Important Note: The information contained in this Design Guide should be used in conjunction with specific local fire codes and standards. Other regional industry practices, where applicable, should also be adhered to.

Contents

1 Background Information

1.1 Fire Safety Considerations in Substations

The major fire risks and detection difficulties within Substations (Figure 1) arise as a result of the following:

- Electrical arcing and the build-up of static electrical charge within equipment.
- Overheating of electrical control equipment, switchgear and cabling.
- Once initiated, a fire may rapidly spread due to the presence of large amounts of combustible material in the form of hydrocarbons contained in cabling and insulation.
- The environment within uninterrupted power supply areas (i.e. battery room) may become explosive from the build up of high concentrations of hydrogen gas.
- Substations are usually unmanned, thus, early intervention by staff may not be possible in the event of a fire.
- High air movement, caused by air-conditioning dilutes and disperses the smoke.
- Much of the mission critical equipment is housed within equipment cabinets and in-cabinet fires may take some time to be detected by ceiling mounted detection devices, especially since in-cabinet fires will usually have prolonged incipient (smouldering) stages.
- Underground cable trenches linking the main areas of the substation are considered hostile environments. High levels of background pollution present in these areas will affect the reliable operation of conventional detectors as well as being a source of false (nuisance) alarms.

Figure 1 – Substation.

1.2 Performance-Based Design

The unique environments within Substations present a challenge to both early and reliable fire detection. There is a high likelihood that detection system performance will be dependent on airflow within the substation. The flexibility of Performance-Based Design, while still following rigorous engineering processes, allows the fire protection system to be tailored to the specific requirements of each individual application's environment.

For example, detector spacing, or, for a VESDA system, sample hole spacing is traditionally dictated by local prescriptive codes and standards. In a Performance-Based Design approach, each installation is assessed according to its specific environmental conditions. Sample hole spacing and location can be altered to suit the particular performance requirements.

The Performance-Based Design approach is widely used since it can provide evidence to justify divergence from prescriptive requirements, particularly in cases where there are practical limitations or a need for an improved level of fire protection.

There are some specific guidelines for the use of Performance-Based Design and risk management concepts. Examples of these are listed below:

- BS 7974 Application of fire safety engineering principles to the design of building – Code of practice [1].
- AS/NZS ISO 31000 Risk management - Principles and guidelines [2].
- SFPE (2000) Engineering Guide to Performance-Based Fire Protection, Analysis and Design of Buildings [3].
- SFPE Handbook of Fire Protection Engineering, Third Edition [4].

Performance-Based fire protection solutions can be made to comply with local and national codes for buildings and life safety. Assessment of the environmental risks and performance requirements, specific to the particular substation, are conducted as part of the design process.

1.3 Key Design Considerations

The following should be considered when designing a VESDA system for a Substation:

1. What are the specific fire risks in each of the operational areas to be protected?
2. What are the environmental conditions in each operational area?
3. To what extent is the substation manned?
4. What do local prescriptive fire codes and standards require?
5. What do Industry codes of practice recommend?

1.4 Why Use VESDA Smoke Detection?

It is essential that fire events in Substation facilities are detected as early as possible to minimize operational disruptions and asset damage. Early fire detection especially becomes critical in unmanned facilities.

The limitations of conventional fire/smoke detectors (point (spot) type smoke, heat and beam-type) must be considered. The comparatively low sensitivity and localized detection of point (spot) type detectors, for instance, can mean that fire events will not be detected soon enough in many cases. Substation environments present the following challenges to conventional detectors:

- Air movement, caused by ventilation, will dilute and cool the smoke plume thus negatively affecting the detection performance of point (spot) type smoke and heat detectors.
- Smoldering fires lack the thermal energy to ascend to the ceiling, thus negatively affecting the detection capability of both point (spot) type smoke and heat detectors.
- Point (spot) type smoke detectors may be subject to continuous environmental changes which may force them to operate outside their recommended operating range (temperature, humidity and airflow velocity) and compromise their detection performance leading to false alarms or reduced sensitivity.
- The maintenance of conventional detectors installed in substations may involve equipment shutdown. Certain codes prohibit maintenance above active arc-resistant switch gear, therefore such equipment must be turned off while detectors are being maintained.
- Maintenance of detectors in cable trenches is difficult due to the inaccessibility of such areas, since the majority of cabling in substations is contained under the floor.
- The high density of equipment in many areas would obstruct the light path of beam-type smoke detectors.

The Very Early Warning Fire Detection (VEWFD) capability of the VESDA system allows it to minimize fire risks and combat detection challenges in the following ways:

- A VESDA system can detect minute amounts of smoke than a point (spot) type detector due to its very sensitive alarm settings and aggregation of smoke-laden air collected through sampling holes at different locations.

- The very early warning capability of the VESDA system allows it to detect fires at the incipient (smoldering) stage. This provides staff with an opportunity to investigate and take action before the fire grows and spreads to adjacent fuels. Should it be necessary, very early warning will increase the time available to execute an evacuation and other emergency plans.
- A VESDA system actively draws air through its sampling holes, which ensures a consistent detection performance in varying airflow conditions. The performance of point (spot) type smoke detectors relies on the direction and magnitude of airflow in their vicinity to carry smoke particulates to the sensing chambers. Consequently, point (spot) type smoke detector performance changes in line with alterations in ventilation conditions.
- There is a comparatively low incidence of false alarms with a VESDA system. This is particularly helpful in unmanned facilities, where investigation is not possible without a site visit.
- In cases where gaseous or sprinkler fire suppression is to be included as part of the overall fire protection system, the VESDA detectors' wide sensitivity range of 0.005 to 20%Obs/m (0.0015 to 6%Obs/ft) means that appropriate alarm thresholds can be set for both early detection and, at a later stage in the fire event, the activation of the suppression release mechanisms.
- The fact that VESDA detectors can be placed in easily accessible locations with only the pipe network being in awkward to reach places, means that they are easier to maintain and requiring no specialist equipment or operation shutdown.
- VESDA systems use a polymeric sampling pipe network which eliminates the potential for corrosion by sulphuric acid in battery rooms. The use of a chemical filter is used to capture corrosive gases in the sampled airstream prior to reaching the VESDA detectors thus ensuring higher reliability and extended operational lifetime of the detection chamber.
- The on-board filter removes the majority of dust from the sampled air stream before it enters the detection chamber, thereby, reducing the likelihood of false alarms and contamination of the optical surfaces. A clean air bleed also keeps the VESDA detector optics free of contaminant build up.
- The ability to network VESDA devices and monitor them remotely makes them ideal for the protection of substations.

2 Design for Effective Fire Protection

2.1 Protection Areas

Table 1 shows the operational areas within a substation in which protection is required.

Table 1 – Substation – Protection Areas.

Areas	Essential	Recommended
Switch/Relay Room		
Ceiling		✓
In/On Cabinet	✓	
Control Room		
Ceiling	✓	
In/On Cabinet	✓	
Floor Void	✓	
Return air vent/Duct		✓
Battery Room		
Ceiling	✓	
Return air vent/Duct		✓
Cable Trench	✓	

2.1.1 Switch/Relay Room

The Switch Room accommodates high density of electronic equipment housed in cabinets and automated switch-gear. In-cabinet equipment maintain the primary functions of the facility and form the switching interface between the Control Room and the field equipment. The area may also accommodate a significant amount of metering and logging equipment. Due to the high volume of critical electronic equipment, it is essential that a fire event be detected before the operation of the plant is compromised.

2.1.2 Control Room

The control room is the main command centre of the substation. The entire operation of the site is monitored and controlled from this central location.

A control room may range from a small, seldom manned, non-ventilated room to a large, air conditioned area containing numerous staff members and electronic equipment (PCs, control panels/consoles, electrical and electronic switching devices, underfloor cabling, etc.).

2.1.3 Battery Room

The Battery Room houses lead acid or nickel cadmium batteries for uninterrupted power supply (UPS) to the substation.

Battery rooms may consist of a slightly corrosive atmosphere (sulphuric acid). It is recommended that a polymeric sampling pipe network is used to eliminate the potential for corrosion. In addition there may be a need to incorporate a 'Chemical Filter' - a special filter designed to absorb corrosive gaseous contaminants. For detailed information refer to the Xtralis Application Note for Chemical Filers [5].

The charge of batteries leads to the evolution of hydrogen gas. If allowed to build up, hydrogen gas can become highly explosive. Under these conditions, the VESDA Exd detector, which is housed in its own explosion proof casing, should be installed.

Note: VESDA detectors are recommended to be mounted external to the battery room, with the exhaust pipe directed back into the protected area.

2.1.4 Cable Trench

A Cable Trench is located under the Switch/Relay Room, Control Room and Battery Room to house the communication, control and power cables between the substation's operational areas as well as transport power to external high voltage switching towers.

The most efficient way to protect a Cable Trench is to install sampling pipe network at the top 10% of the trench's height (Figure 2).

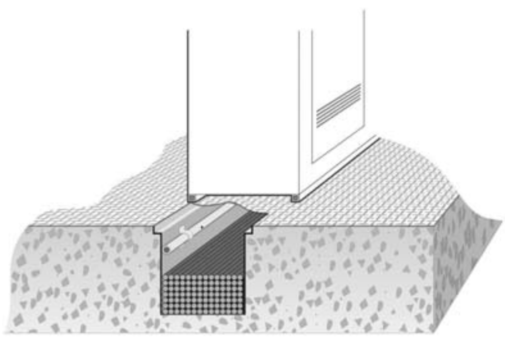

Figure 2 – Cable Trench protection.

Note: In-line filters should be used in this environment to protect the VESDA detector from exposure to excessive amounts of pollution. For detailed information refer to the Xtralis Application Note for In-line Filters [6].

2.2 Ceiling Protection

The sampling pipe network is installed under the ceiling where the sampling holes form a grid pattern (Figure 3). Local codes and standards should be consulted in determining the spacing of the sampling holes.

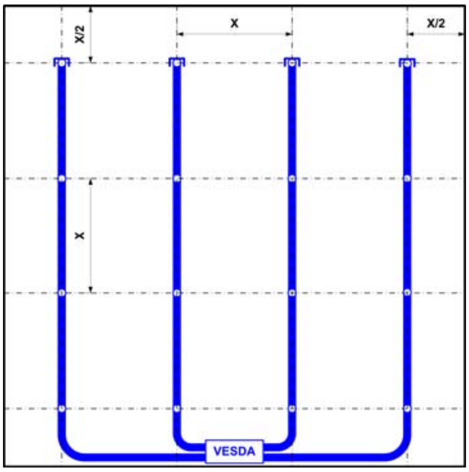

Figure 3 – Ceiling protection grid layout.

Important Note: All sampling pipe network configurations should be verified using the ASPIRE2™ Pipe Network Modelling Program.

2.3 Floor Void Protection

Floor voids contain large quantities of electrical cabling and in conjunction with high airflows present a risk of rapid spread of fire. It is, therefore, very important that these areas are protected. VESDA detectors are well suited to this task with the detector positioned outside the floor void at an accessible location convenient for service and maintenance personnel. Mounting the detectors outside the floor void also minimizes any disruption to normal business operations during maintenance.

In order to prevent the build up of dust and dirt, sampling holes are drilled on the underside of the sampling pipe (Figure 4). Sampling hole spacing is determined by the grid method (Figure 3).

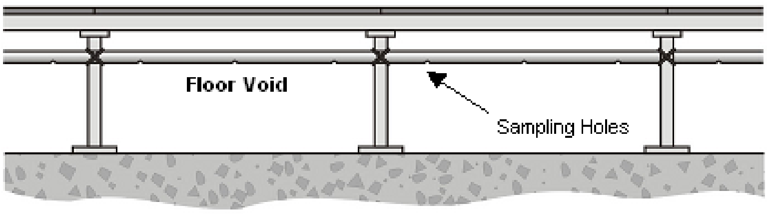

Figure 4 – Example of floor void protection.

The following should be adhered to when protecting floor voids:

- The VESDA exhaust should be returned to the protected area to minimize effects of possible pressure difference between the protected area and the area in which the detector is located.
- Sampling pipes should be stand-off mounted to provide clearance from cabling at the top of the void.

2.4 In/On-Cabinet Protection

Cabinets containing electrical equipment are usually ventilated either vertically (from bottom to top) or horizontally (from front to rear). There are also fully enclosed cabinets with active internal cooling and ventilation. Fires within these areas may not be detected until they have been in progress for some time and have caused considerable damage to the housed equipment.

There are two methods for protecting cabinets with VESDA detectors:

- In-Cabinet Protection.
- On-Cabinet Protection.

In-Cabinet protection is achieved using either of the following two options:

1. The sampling pipe is placed inside the cabinet. This provides optimum detection and is commonly used by cabinet OEMs (Original Equipment Manufacturers) for both sealed and ventilated cabinets. In ventilated cabinets (both vertical and horizontal), air is sampled as it reaches the exit points.
2. A capillary tube (A) or down pipe (B) can be inserted into the top of the cabinet from the main ceiling mounted sampling pipe (Figure 5). This arrangement is suitable only for sealed cabinets or cabinets with little ventilation (vertical).

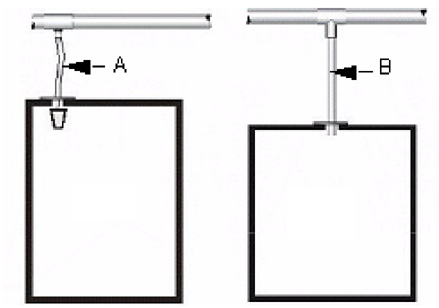

Figure 5 – Example of a capillary tube (A) and down pipe (B) used for In-Cabinet sampling.

For On-Cabinet protection, the sampling pipe is placed at exits of airflow from the cabinets with the sampling holes directly in the path of the main airflow. Figure 6 shows an arrangement suitable for vertically ventilated cabinets. Similarly, a front-to-rear vented cabinet can be protected by sampling pipe vertically mounted at back of the cabinet. One detector can be used to protect a number of cabinets.

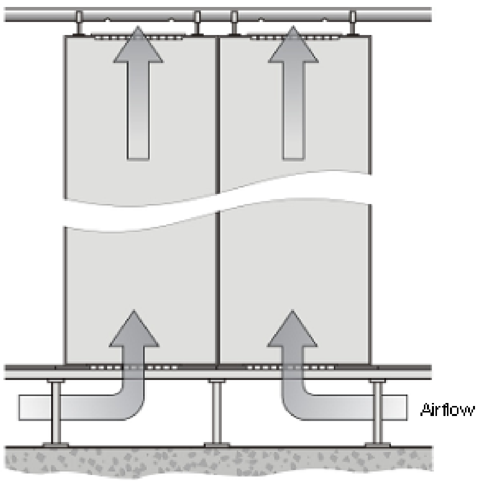

Figure 6 – Example of On-Cabinet protection.

Notes:

- For in cabinet protection, unless otherwise specified, it is recommended that capillary tubes penetrate the cabinet to a depth of 25 to 50 mm (1 to 2”).
- When rapid response to an incipient fire event is required, individual VESDA detectors or dedicated sampling pipes from an addressable VESDA detector (such as VESDA VLS or VFT-15) can be used to identify the location of the smoke source. Fire events can then be traced to a particular cabinet or row of cabinets.
- Care must be taken when installing capillary tubes in cabinets with extraction fans. These fans may cause low pressures within the cabinet which could prevent air and hence smoke entering the sampling hole. In this case, sampling downstream (outside the cabinet) from the extraction fans may be considered.

2.5 Return Air Vent/Duct Protection

The smoke from incipient electrical fires lacks thermal buoyancy and will most likely follow the path of the air circulated by the Air Handling Unit (AHU) (Figure 7). The effect of this air movement on smoke detection at the ceiling can be overcome by complementing ceiling sampling with sampling across the return air vent of the AHU. Placing VESDA pipes on the return air vent will increase the reliability of smoke detection since smoke will be detected as early as possible.

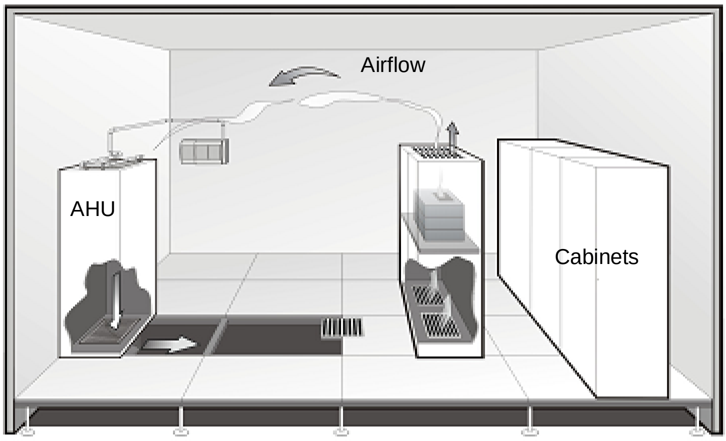

Figure 7 – Example of return air vent protection.

Changing airflow conditions across the return air vents, caused by a change in the operation of the AHU, may cause flow faults at the detector. These flow faults are avoided by positioning the VESDA sampling pipe 100 to 200 mm (4 to 8") away from the return air vent by using stand-offs and by orientating the sampling holes at an angle of 30° to the direction of airflow (Figure 8), rather than having them facing the incoming air.

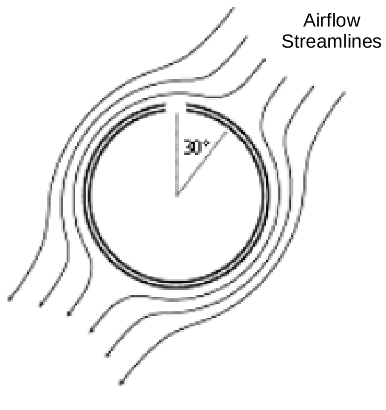

Figure 8 – Example of sampling hole at 30° angle to the incoming air.

It is possible to monitor more than one AHU with a single VESDA detector, provided that the AHUs' are in close proximity to one another. A good design practice is to restrict the VESDA system transport time to between 30 and 40 seconds (determined by ASPIRE2™).

In summary, it is important to consider the following points when designing for return air vent protection:

- The use of sampling pipe stand-offs from the return air vent is critical, especially when multiple AHUs' are being monitored by the same detector.
- For very early warning smoke detection, air sampling should be conducted upstream from the AHU filters to avoid the removal of smoke from the air before it is sampled.
- In cases where the AHU being monitored requires front access for maintenance, removable VESDA pipes must be used. These pipes have special socket junctions to ensure the correct pipe orientation with respect to the airflow direction (30°) on reconnection.
- Good pipe network design practices such as minimizing the total pipe length and number of bends should also be considered. Non-vented end-caps should be used.

It is essential to test the system performance, with the AHUs' in their normal operating mode and turned off, to check that sampling pipe position and orientation are correct. The movement of smoke towards the AHU may be impeded by the cabinets. It is a good practice to use VESDA detectors to monitor the entire area (ceiling, voids and return air vents), hence providing an integrated total early warning solution. All sampling pipe network designs must be verified by the ASPIRE2™ Pipe Network Modelling Tool.

Note: Local codes and standards should be consulted in determining the spacing of the sampling holes

Note: The ASPIRE2™ Pipe Network Modelling Tool must be used to ensure that the transport time is within acceptable limits.

In-Duct Sampling is achieved by locating a sampling pipe across the entire width of the duct (Figure 9). For very early warning smoke detection, air sampling should be conducted upstream from the filters to avoid the removal of smoke from the air before it is sampled.

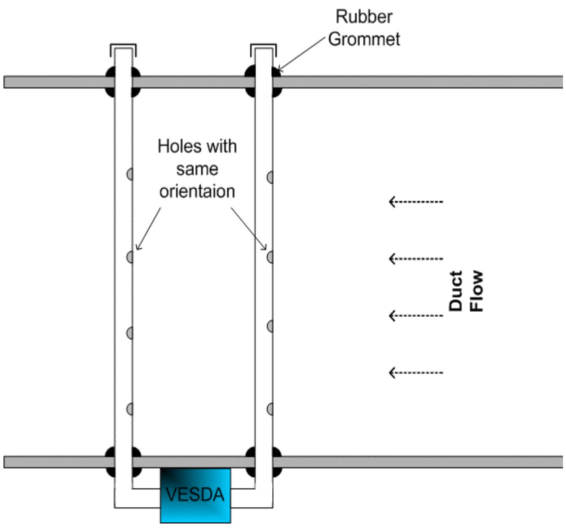

Figure 9 – Duct sampling.

For detailed information refer to the Xtralis Application Note for Ducts [7].

3 Ongoing Considerations

3.1 System Commissioning

Once the VESDA system has been installed, its performance and pipe network integrity can be verified from commissioning tests by comparing against to the parameters computed by the ASPIRE2™ pipe network modelling program. A range of sampled air temperatures may be input to determine Maximum Transport Times for each zone. Calculated Transport Times should be applied conservatively. Smoke tests can then be used to check system performance for both smoke detection and pre-action suppression activation.

3.2 Service and Maintenance

The VESDA system shall be serviced and maintained according to local codes and standards and the instructions provided in the Maintenance section of the VESDA System Design Manual [8].

Note: VESDA detector on-board filters may require more frequent replacement where the detector is installed in the dirty environment of the cable trenches, particularly where no in-line filtering is being used.

4 References

[1] BS 7974 (2001) Application of fire safety engineering principles to the design of building – Code of practice.

[2] AS/NZS ISO 31000 (2009) Risk management - Principles and guidelines.

[3] SFPE (2000) Engineering Guide to Performance-Based Fire Protection, Analysis and Design of Buildings.

[4] SFPE (2002) Handbook of Fire Protection Engineering, 3rd Edition.

[5] Xtralis Chemical Filter for Corrosive Environments Application Note (doc. No. 14888).

[6] Xtralis In-line Filter Application Note (doc. No. 17785).

[7] Xtralis Ducts Application Note (doc. No. 10760).

[8] Xtralis VESDA System Design Manual, Ed. 4.5.

Disclaimer on the Provision of General System Design Recommendations

Any recommendation on system design provided by Xtralis is an indication only of what is considered to be the most suitable solution to meet the needs of the common application environments described.

In some cases the recommendations on system design provided may not suit the unique set of conditions experienced in a particular application environment. Xtralis has made no inquiry nor undertaken any due diligence that any of the recommendations supplied will meet any particular application. Xtralis makes no warranty as to the suitability or performance of any recommendation on system design. Xtralis has not assessed the recommendation on system design for compliance with any codes or standards that may apply nor have any tests been conducted to assess the appropriateness of any recommendations on system design. Any person or organization accessing or using a recommendation on system design should, at its own cost and expense, procure that the recommendation on system design complies in all respects with the provision of all legislation, acts of government, regulations, rules and by-laws for the time being in force and all orders or directions which may be made or given by any statutory or any other competent authority in respect of or affecting the recommendation on system design in any jurisdiction in which it may be implemented.

Xtralis products must only be installed, configured and used strictly in accordance with the General Terms and Conditions, User Manual and product documents available from Xtralis. Xtralis accepts no liability for the performance of the recommendation on system design or for any products utilized in the implementation of the recommendation on system design, aside from the General Terms and Conditions, User Manual and product documents.

No statement of fact, drawing or representation made by Xtralis either in this document or orally in relation to this recommendation on system design is to be construed as a representation, undertaking or warranty.

To the extent permitted by law, Xtralis excludes liability for all indirect and consequential damages however arising. For the purposes of this clause, 'consequential damage' shall include, but not be limited to, loss of profit or goodwill or similar financial loss or any payment made or due to any third party.

Recommendations on system design are provided exclusively to assist in design of systems using Xtralis products. No portion of this recommendation on system design can be reproduced without the prior approval in writing of Xtralis. Copyright and any associated intellectual property in any such recommendations on system design or documentation remains the property of Xtralis.

www.xtralis.com

The Americas +1 781 740 2223 **Asia** +852 2916 8894 **Australia and New Zealand** +61 3 9936 7000
Continental Europe +32 56 24 19 51 **UK and the Middle East** +44 1442 242 330

Doc. 11737_00