TURBINE FIRE PROTECTION

Effective fire detection and suppression has become a top priority for turbine manufacturers and wind farm operators. Firetrace International explains why.

By Scott Starr

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WITH GOVERNMENTS ACROSS the globe becoming ever more aware of the environmental benefits of wind-generated power, the number of wind farms and the financial investment in constructing, erecting, and maintaining wind turbines is increasing exponentially. Today the market is estimated to be worth $60 billion annually, with global wind capacity expected to double every three years. According to the World Wind Energy Association's (WWEA) "World Wind Energy Report 2009" the United States is the world leader in terms of the installed capacity of wind power, followed by China, Germany, Spain, and India. WWEA figures show that last year these five countries together accounted for nearly 80 percent of worldwide wind capacity.

Such a high level of investment, coupled with the increased dependence on wind power, has led turbine manufacturers and operators to become acutely aware of the financial implications, safety issues, and environmental impact of fire-damaged or destroyed turbines. Indeed, fire safety has become such an issue that the United States' National Fire Protection Association (NFPA), Germany's Vertrauen durch Sicherheit (VdS), and Germanischer Lloyd have developed recommendations, standards, or codes of practice.

The NFPA has recently added wind turbine and outbuilding fire protection standards to NFPA 850, titled "Recommended Practice for Fire Protection for Electric Generating Plants

Fig. 2: A wind turbine protected by Firetrace in the French countryside.

and High Voltage Direct Current Converter Stations, 2010 Edition." This document provides fire protection recommendations for the safety of construction and operating personnel, physical integrity of plant components, and the continuity of plant operations. The revised 2010 edition includes detailed recommendations relating to wind turbine generating facilities.

VdS 3523en (wind turbines, fire protection guideline) has also been used as the basis for the CFPA E, or Confederation of Fire Protection Associations in Europe, guideline no. 21.2010 F, which addresses the same topic. VdS is a highly-regarded, independent, international, third-party accreditation and certification body for fire prevention and safety technology. Germanischer Lloyd, which specializes in classifications for the maritime and energy industries, has developed Renewables Certification Guidelines: "GL Wind Technical Note Certification of Fire Protection Systems for Wind Turbines, Certification Procedures, Revision 2, Edition 2009."

SCALE OF THE PROBLEM

A report by the AREPA Group—a technical service organization with operations throughout Europe that specializes in the assessment and restoration of damaged technical equipment—suggests that 184 wind turbine components were damaged by fire since 2002, while the Caithness Windfarm Information Forum believes that, as of September 2009, 122 wind farm fire incidents were reported globally. The cost of property damage on each of these reported incidents spans from $750,000 to $2 million.

However, many in the industry believe that these figures grossly underestimate the scale of the problem. A significant number of turbine fires go unreported, possibly because of a combination of their remote location and the fact that the emergency services are not always called upon to attend, and these fires do not form part of any official fire incident statistic.

TURBINE FIRE RISK

The almost inevitable consequence of these industry initiatives has been that a number of detection and suppression systems have been put forward as suitable solutions. While many are effective for what might be regarded as "conventional" applications, they may not be suitable for the particular fire challenges found in wind turbines.

The majority of turbine fires are started by a lightning strike, brought about by their exposed and often high-altitude location and the height of the structure; turbines are now being built that are up to 320 feet high. Mechanical failure or electrical malfunction also account for a significant percentage of fires that can be fuelled by up to 200 gallons of hydraulic fluid and lubricants in the nacelle, which itself is constructed from highly-flammable resin and glass fiber. Internal insulation in the nacelle, which can become contaminated by oil deposits, add to the fuel load.

Electrical equipment is another high-risk area. Capacitors, transformers, generators, electrical controls, and transmission equipment all have the potential to catch fire, as do Supervisory Control and Data Acquisition (SCADA) systems. There is also the risk of fire due to loose or broken electrical connections or the overloading of electrical circuits.

Braking systems pose a particularly high fire risk. Overheating can cause hot fragments of the disc brake material to break off, rupturing hydraulic hoses and resulting in highly combustible hydraulic fluid being expelled under pressure and coming into contact with the hot disk brake fragments. Hydraulic pumps and connections have also been known to fail, allowing the fluid to erupt into flames when it comes into contact with a hot surface.

UNIQUE FIRE PROTECTION CHALLENGE

What are the special challenges that an effective fire detection and suppression system for a wind turbine have to overcome? The core issue, of course, is remoteness. This is particularly the case with offshore wind farms, but even onshore farms are routinely in difficult to access or isolated locations. The essential characteristics of an effective wind turbine fire detection and suppression system are that it should:

- Deliver around the clock reliability and 24/7 unsupervised protection;
- Ensure an absence of false alarms;
- Contend with vibration, dust, debris, and airflow through the nacelle;
- Contend with extreme temperature variations;
- Stop a fire precisely where it breaks out, and before it takes hold;
- Require no external power.

The options that are often considered can be generally categorized as air sampling detection; water mist suppression; compressed-air foam suppression; fusible link detection and suppression; total flooding CO_2 (carbon dioxide) suppression; total flooding clean agent suppression; and linear pneumatic detection and suppression.

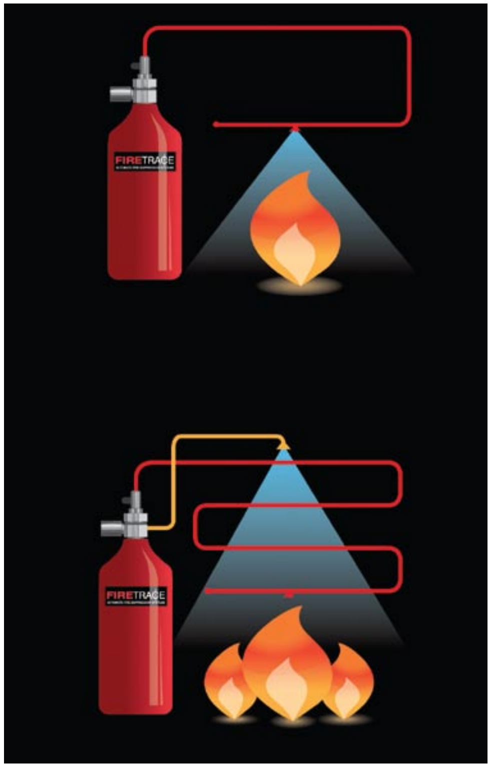

Fig. 3: A schematic diagram of the Firetrace system.

Air sampling aims to offer early detection by collecting minute smoke particulates in the early stage of fire, but they do require a power source and control panel, which means that the system will fail if the external power or battery backup fails. These systems are also expensive, in part because they only detect a fire, and so need to be integrated with a suppression system.

The major drawback to air sampling in wind turbines, though, is the ever-present risk of false alarms. These can be caused by tiny particles of dust and debris and atmospheric pollution that are propelled around the nacelle due to the turbine housing having a number of openings to allow air to circulate to reduce the internal temperature. While false alarms are the bane of any system owner's life, a false alarm in a wind turbine inevitably involves extensive travel and possibly the hiring of expensive specialist access equipment.

SUPPRESSION-ONLY SYSTEMS

Water mist suppression systems convert water into a fine atomized mist, but they too have limitations when used to protect wind turbines. Due to the turbine's remote location and the distance from the ground to the nacelle, water mist systems are often impractical, plus they call for considerable space to be devoted to water storage, which increases the weight in the nacelle. These systems are also a costly part-solution to the problem, as they need to be linked to a detection system.

Water mist systems are total flooding solutions, which increase the potential for damage to electrical components and possible corrosion. Also, because in some locations the temperature can fall below freezing point, antifreeze has to be added to the water, and antifreeze is a combustible liquid that is itself a corrosive substance.

Compressed air foam systems work on the principle that compressed air is injected into a foam solution to achieve a quicker fire knockdown when compared with conventional foam systems. While they need less water than conventional systems, the storage, weight, and freeze-protection problems are similar to those of water mist systems. In addition, these systems require considerable extra space for the operating components. After discharge cleanup can be extensive and, like water mist systems, the cost is increased by the need for a separate detection system.

Fusible link systems, however, do combine detection and suppression into one package and work on the basis that heat from a fire will rupture a fusible link—the detection element—that in turn will initiate the discharge of the suppressant. The challenge with these systems is that airflow in the nacelle can seriously impair performance and reliability because heat and flame that typically rise from the source of a fire may be propelled away from the location of the fusible link, critically delaying activation.

TOTAL FLOODING GASEOUS SYSTEMS

Whether using CO_2 or the latest clean gaseous agents, traditional total flooding suppression systems are designed to fill the entire space being protected with suppressant. While an established suppression agent, CO_2 is not without its drawbacks. It is unsuitable for total flooding applications in potentially occupied enclosures, as its discharge in fire extinguishing concentrations would be lethal to occupants. Flooded areas must be adequately ventilated after discharge to prevent accidental exposure of personnel to dangerous levels of CO_2 when investigating the cause of a discharge.

These challenges do not exist with clean agents, however, such as 3M™ Novec™ 1230 fire protection fluid. The suppressant is stored as a low vapor-pressure fluid that, when discharged, vaporizes into a colorless and odorless gas. Typical total flooding applications use a concentration of the fluid that is well below the agent's saturation or condensation level, and its low design concentration means that less space has to be devoted to cylinder storage. Novec 1230 has a negligible impact on the environment, with insignificant global warming potential, zero ozone depletion, and an atmospheric lifetime of just five days. Once discharged it leaves nothing behind to damage sensitive electronic equipment.

Traditional total flooding systems are not without any downsides. Vibration can loosen connections while dirt, dust, and temperature extremes are known to cause unwarranted discharge. Additionally, openings in the turbine housing significantly inhibit achieving the designated agent concenwration. Devising a solution to overcome these challenges can add significantly to the weight in the turbine.

INTEGRATED DETECTION AND SUPPRESSION

The major drawbacks of traditional total flooding suppression systems, and the shortcomings of other technologies put forward for the protection of wind turbines, are overcome in the Firetrace® linear pneumatic system that provides both fire detection and suppression in a single package. It is a self-contained system that, significantly, requires neither electricity nor external power; a solution that is activated automatically around the clock without the need for manual activation or monitoring, and it requires virtually no maintenance. It is an intrinsically safe solution as it does not contain any components that produce sparks, or that can hold enough energy to produce a spark of sufficient energy to cause an ignition.

Firetrace is comprised of a cylinder that for wind turbine applications contains 3M Novec 1230 and is attached to a purpose-designed proprietary Firetrace detection tubing via a custom-engineered valve. This leak-resistant polymer tubing is a linear pneumatic heat and flame detector that is designed to deliver the desired temperature-sensitive detection and delivery characteristics. It is routed throughout the areas to be protected and, when the tubing is exposed to heat and radiant energy from a fire, it ruptures and instantly directs the suppression agent at the source of the fire.

With over 150,000 Firetrace systems installed around the world, a key factor in its success is the system's reliability. The fact is that the only thing that will rupture the tube is heat or flame from a fire, so there is no prospect of false alarms. Yet if a fire breaks out, the response is unerringly immediate and accurately targeted. It is the only Underwriters Laboratories (UL) listed, Factory Mutual (FM) approved, and Conformité Européene or European Conformity (CE) marked tube-operated system in the world that is tested as an automatic fire detection and suppression system.