New Jersey Small Wind Turbine Failure Analysis: Xzeres 442 Wind Turbine, Villas, New Jersey

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Table of Contents

List of Figures

Introduction

On January 8, 2011, a failure in the controls of a wind turbine at the residence of Mr. Dennis Hasson, in Villas, New Jersey, caused fires in the turbine nacelle at the top of the 97-foot tower and the turbine control electronics located in the residence's garage.

The wind turbine was a Xzeres Wind Corporation Model 442, which has a rotor diameter of 23.6 feet, a rated power of 10 kilowatts (kW) at 25 mph (11 meters per second), and a "swept area" of 442 square feet (hence the name). The turbine has been replaced with a completely new unit by Xzeres (with electrical design improvements incorporated), shown in Figure 1.

This report addresses the chronology and reasons for the incident, estimates future risks for this and similar products, and makes a number of recommendations based on the analysis.

Figure 1. The replacement turbine at the Villas, New Jersey, site
(*Photo by Rob Wills, Intergrid, LLC*)

The Xzeres incident caused no secondary fire or mechanical damage, no people were hurt, and the turbine remained mechanically intact despite the complete loss of its electronic control system. The initial problem and probable root-cause was a wire short-circuit between the low-voltage control wiring and high-voltage control wiring in the turbine diversion load. This caused all normal turbine control (possibly including over-speed braking) to be inoperative. The turbine then went into over-speed, creating excessive output voltages that caused a cascading sequence of failures in the turbine control box, inverters, and turbine nacelle.

Methodology

The methodology used during the investigation was as follows:

1. Collect as much first-hand information as possible from the owner, installer, and manufacturer
2. Examine available failed components
3. Identify possible root causes and the sequences of events
4. Analyze available data, including information regarding similar incidents
5. Identify possible manufacturing, installation, or operational errors
6. Determine whether this was an isolated incident or if the product poses an ongoing risk
7. Generate conclusions and recommendations.

The authors of this study, Dr. Robert Wills and Lee Jay Fingersh, attended a kickoff meeting on November 29, 2011, and met with the turbine installers (JBS Solar and Wind of Cape May, New Jersey) later the same day. They visited the Villas, New Jersey, site on November 30, 2011, and inspected the replacement turbine installation.

In December, JBS Solar shipped the failed turbine's alternator stator, controller, diversion loads, and inverters to the National Wind Technology Center (NWTC) at the NREL near Boulder, Colorado, for inspection.

Dr. Wills and Trudy Forsyth (of the NWTC) discussed the incident with Frank Greco, chief executive officer of Xzeres Corporation, on December 27, 2011. Frank and his staff were very cooperative and provided all materials requested by the investigators. Dr. Wills signed a nondisclosure agreement with Xzeres that gave him access to the company's schematic diagrams and internal report documents.

Dr. Wills traveled to the NWTC and worked with Lee Jay Fingersh on January 4, 2012, to examine and evaluate failed components, including the turbine controller, diversion loads, inverters, and turbine alternator stator. The turbine up-tower brake components were not available for inspection.

Description of the Incident

On January 7, 2011, the Cape May area (near Villas, New Jersey) experienced sustained high winds (30–50 mph gusting to perhaps as much as 80 mph). At approximately 12:30 a.m. on January 8, 2011, Dennis Hasson, owner of the Xzeres wind turbine, was alerted to a burning smell in his house by a guest. Mr. Hasson entered the residence's garage where he found flames and smoke coming from the turbine controller. He also noticed that both diversion loads (seen on the back wall in Figure 2) were glowing red.

Figure 2. Turbine control box with the emergency stop button in the foreground

(Photo by Rob Wills, Intergrid, LLC)

Mr. Hasson attempted to disable the turbine by first pressing the emergency stop (E-Stop) button on the controller (Figure 2), and then by turning off circuit breakers that feed the turbine controls and the two SMA inverters that are part of the wind system (see Figure 4 for details). The circuit breaker panel can be seen in the center of Figure 2, with the two SMA Windy Boy inverters just to the right, behind the turbine controller.

Mr. Hasson then went outside and opened both turbine disconnect switches (one on the house and one at the base of the turbine tower). These switches are shown in Figure 3.

Figure 3. External turbine disconnect switches

(*Photo by Rob Wills, Intergrid, LLC*)

Under normal conditions, any of these actions (using the E-Stop button, removing alternating current (AC) power, or opening a turbine disconnect) should result in the turbine coming to a safe condition (turbine rotor slows to a safe idle or stopped condition), and all electric sources are isolated from the turbine controls and house wiring. On January 8, 2011, Mr. Hasson's actions controlled the fire in the garage, however, the turbine did not stop. Despite the opening of the disconnect switches, the turbine nacelle and alternator windings heated to the point that the winding varnish caught fire.

Eye witnesses said that the turbine at this time was very noisy, and that there was a large amount of tower vibration. This is typical of over-speed operation of a turbine rotor. The turbine installer, fire department, and police department were called shortly after the fire was discovered and were on site at approximately 1 a.m.

Attempts to stop the turbine by shorting the alternator output were unsuccessful. High winds prohibited work on the turbine, which continued to spin for the next month. Although the turbine's electrical braking system was damaged and not operating, the redundant speed control mechanism of a furling tail mechanism operated, providing some speed control. This is apparent from a newspaper report that stated that a neighbor "said that the following morning when he viewed the aftermath of the fire, the tail piece was sticking straight up in the air."

Two engineers from Xzeres visited the site on January 13, 2011. They took photographs and analyzed the failure, but were unable to examine up-tower components. The wind finally abated and the turbine stopped spinning in February 2011. JBS Solar and Wind then tilted down the 97-foot lattice tower and replaced the turbine and controls.

System Components and Safety Systems

The Xzeres 442 Grid-Connected Power System consists of a 10-kW (nominal) wind turbine, rectifiers, inverters, and control system (Figure 4).

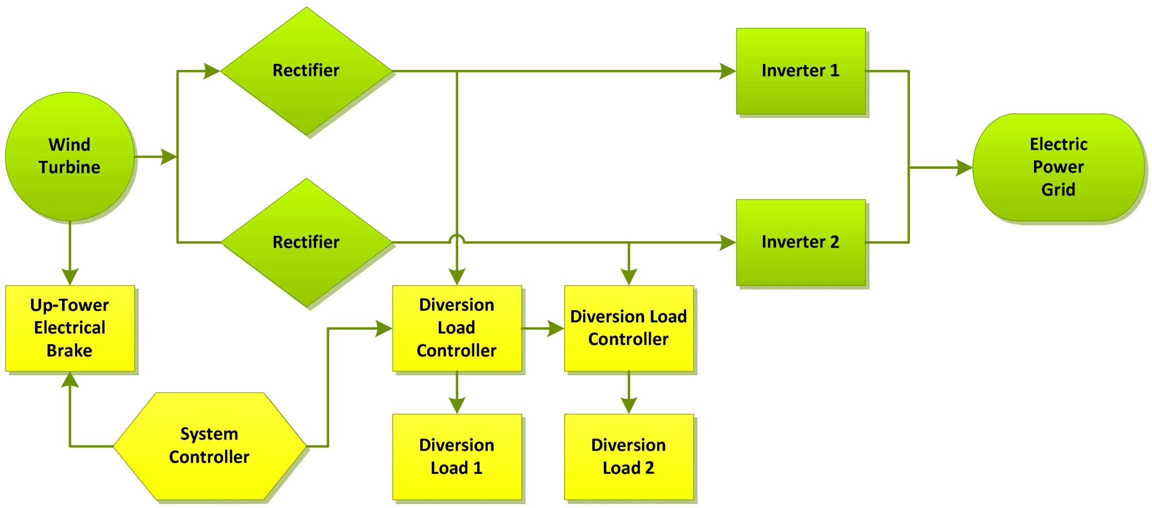

Figure 4. Xzeres 442 turbine major system components
(*Illustration by Rob Wills, Intergrid, LLC*)

Additional details include the following:

- The wind turbine has three 12-foot blades connected to a permanent magnet rotor. This generates electric power in windings of copper wire known as a stator. The turbine is mounted on top of a 97-foot free-standing lattice tower.
- The rectifiers convert AC from the turbine generator to direct current (DC) that feeds the inverters
- The two SMA Windy Boy 6-kW inverters convert DC power back to AC power. They synchronize with and feed power into the electric power grid.
- The two diversion load controllers (technically IGBT chopper circuits) send power to the diversion loads if the wind turbine output exceeds the export capability of the inverters, or if the electric grid is not available.
- The up-tower electrical brake consists of three power resistors connected to the turbine alternator via a normally closed electrical contactor. The 24-volt alternating current (VAC) coil of this contactor must be energized to allow the turbine to spin.
- The system controller is a small, single-board microcomputer. It controls diversion loads and the up-tower brake, operates front panel indicator light-emitting diodes (LEDs), and takes inputs from the E-Stop button on the controller and the thermal cutout sensors in the diversion loads. If a diversion load overheats, the controller will bring the turbine to a stop (actually a slow, controlled motion often called "idling").

Possible Manufacturing, Installation, or Operational Flaws

Root Cause

The root cause of the incident, as determined by Xzeres and the authors of this report, was an accidental contact between a 24-volt (V) control wire used to detect over-temperature in the turbine's diversion load and a load resistor that was connected to high-voltage DC at the time. The control wire actually welded to the load resistor as can be seen in Figure 5, which also shows the thermal sensor.

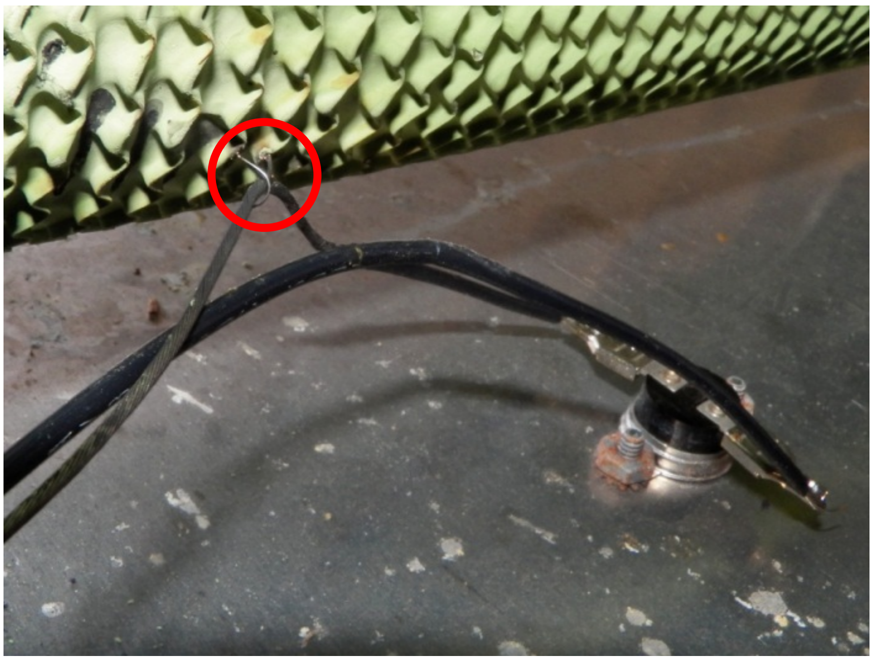

Figure 5. Thermal sensor in diversion load with control wire welded to resistor body
(*Photo by Lee Jay Fingersh, NREL*)

Manufacturing Flaw or Deformed Case?

The thermal sensor wiring in the turbine diversion load is suitably rated for the temperatures expected in the diversion load, but was not adequately restrained to ensure that it could not contact the resistor body (Figure 6).

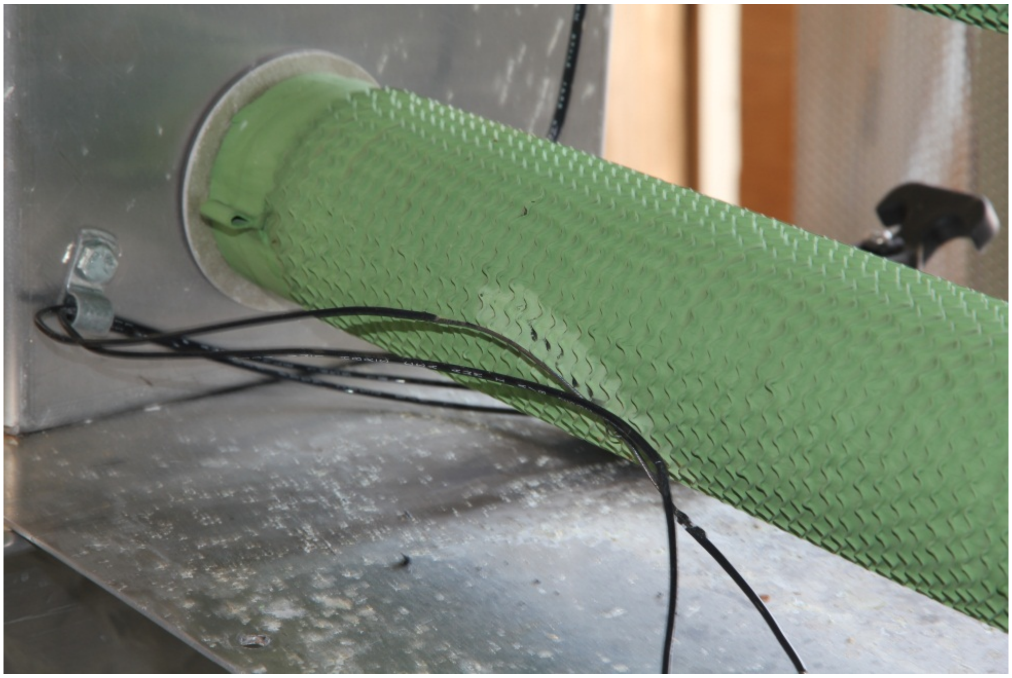

Figure 6. Lack of wire restraint in the diversion load
(*Photo by Lee Jay Fingersh, NREL*)

There were reports of a heating, ventilating, and air conditioning (HVAC) contractor working around the diversion loads and deforming the case, causing this problem. We did observe deformation of the case, but it is unlikely that it contributed significantly to the problem. The fact remains that the wires were inadequately constrained.

Xzeres has taken several steps to remedy this problem in current production. For example, right-angle connectors are now used on the thermal sensor and additional wire restraints are used to ensure that contact with the resistor body cannot occur (Figure 7 shows the interior of the replacement diversion load now installed at the Villas site).

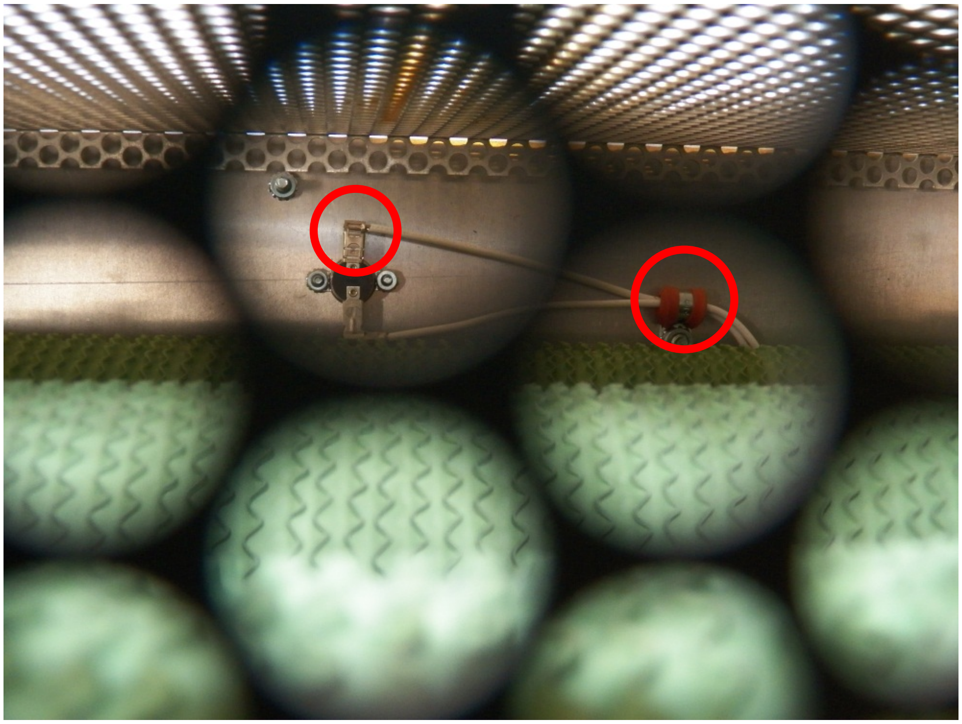

Figure 7. Improved wire restraint in diversion load
(*Photo by Rob Wills, Intergrid, LLC*)

Xzeres manufacturing drawings dated January 20, 2011, indicate that attention was paid to this issue promptly and effectively (Figure 8).

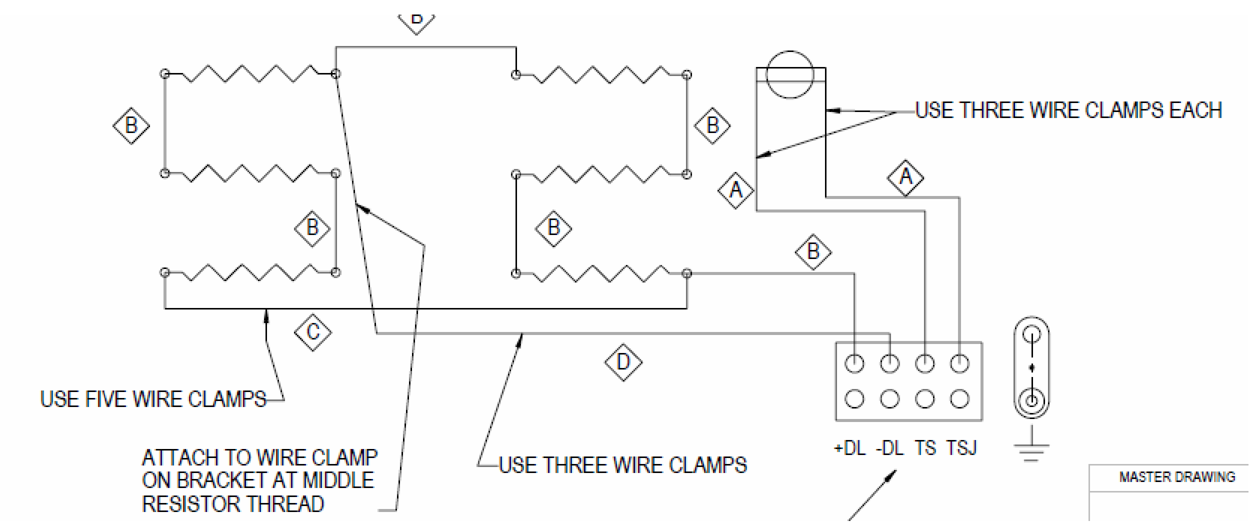

Figure 8. Excerpt from Xzeres manufacturing drawings
(*Illustration by Xzeres*)

Installation Issues – Disconnect Interlocks

Discussions with the installer and the Xzeres internal incident report both identified the installation of turbine disconnect switches without brake interlock contacts as a potential safety hazard. As described above, the Xzeres 442 uses electrical braking with up-tower resistors and a normally closed contactor (also in the turbine nacelle). Removal of 24 VAC power from the contactor coil causes the brake to apply; this turbine installation (prior to the replacement) did not have these installed.

The Xzeres installation manual (Xzeres 2010) is very clear about the above requirement:

> "NOTE: Your local code may require a disconnect switch at the tower base. If you install a disconnect switch on the turbine power wires you MUST also install auxiliary contacts that disconnect the four 14 AWG brake control wires."

The Xzeres manual provides similar language for additional disconnect switches. This installation omission did not, but could have, caused a problem. The redundant speed control (i.e., furling tail) of the Xzeres 442 turbine would have limited rotor speed in the event of a switch being opened. This potential problem has been resolved; both disconnect switches now have brake interlock switches installed (Figure 9).

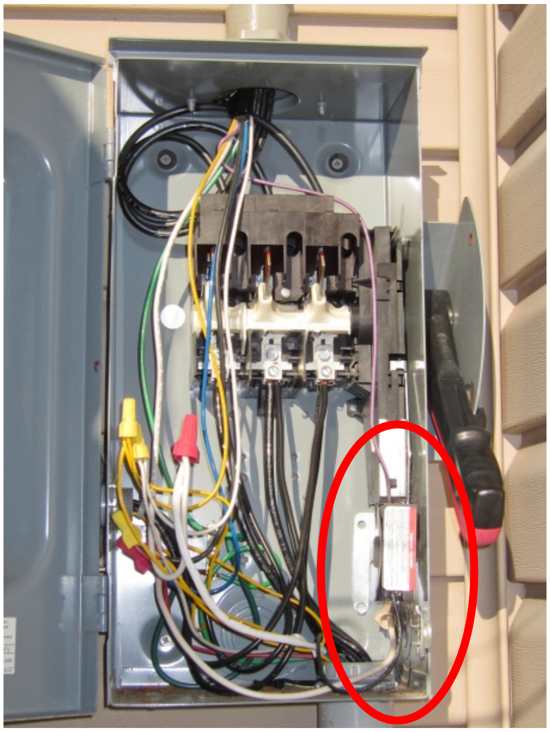

Figure 9. Turbine disconnect with interlock (lower right) installed
(*Photo by Lee Jay Fingersh, NREL*)

The lack of interlocks in the turbine disconnects had no impact on the incident in question as all AC power was removed from the turbine and controls prior to the disconnect switches being opened. This should have operated the turbine's internal electric brake.

Installation Issues – Mounting of Diversion Loads

The Xzeres 442 installation manual includes the following caution:

> **CAUTION**
>
> The Diversion Loads can dissipate as much as 18 kW of heat. The exterior surfaces get hot and the hot air emitted from the Diversion Loads must not be restricted. Follow all clearance specifications (see Section 4.2.1.4 for clearances).
>
> *Never place objects on or near* the Diversion Loads.
>
> — Keep Diversion Loads Clear! —

It then goes on to state the following clearance requirements and mounting position:

> 4.2.1.4 The diversion loads need space around them to ensure proper air flow during operation. Verify the following clearances exist around each diversion load:
>
> • Top: 18 inches
>
> • Bottom: 12 inches
>
> • Sides: 3 inches between diversion loads
>
> • Sides: 3 inches to a wall or other surface
>
> 4.2.1.5 Mount the diversion loads *side by side* on the board so they are horizontal, and the terminal block is in the lower right-hand corner.

Note: The above emphasis on side by side is ours—it is not overly clear in the installation manual.

The present installation of diversion loads does not comply with the manufacturer's installation instructions, both in top clearance for the bottom load and the side-by-side requirement (Figure 10). This lack of compliance could have contributed to the incident as high temperatures could have caused a wire to droop.

Figure 10. Mounting of diversion loads
(*Photo by Lee Jay Fingersh, NREL*)

It is recommended that the diversion loads in the current installation be re-mounted according to the manufacturer's instructions, or if that is not possible due to wall space limitations, re-arranged according to the manufacturer's direction regarding sufficient spacing and clearance.

Installation – General

Apart from these two issues, the installation of the Xzeres turbine in Villas was performed in an exemplary manner. Wiring and mounting are neat and workmanlike, and the installation appears to be in full compliance with the National Electrical Code, especially Article 694, Small Wind Electric Systems (NEC 2008).

Operator Action

The owner's, Dennis Hasson's, actions during the incident were completely appropriate and correct in the circumstances. There was some question of this in local newspapers (from pressofatlanticcity.com):

> "One expert told Press staff writer Richard Degener that the Lower Township fire probably was the result of operator error or installer error and shouldn't be used to justify more regulations on wind power. Fair enough. Clearly, these fires are rare. But there will be more of them, and fire departments need to be prepared."

Mr. Hasson: actuated the turbine E-Stop button, cut power to the controls and inverters that were on fire, and opened the external turbine disconnects to remove turbine power from the building. These actions were entirely appropriate for the circumstances.

Fact Findings and Determination of Causes

Root Cause

Our determination of the root cause of the incident is that a low-voltage control sense wire in a diversion load contacted and became welded to a load resistor, causing damage to the turbine control system. This accidental contact can be attributed possibly to three factors:

A. Lack of wire restraints (manufacturing error)

B. High operating temperature (installation error)

C. Mechanical disturbance (post-installation).

This event cannot re-occur at the present turbine site or at new Xzeres 442 site installations as great care has been taken to ensure that control wires are sufficiently restrained.

Failure Cascade

1. High voltage (HV) fed to controller

The operating DC bus voltage for the system is about 350 V. Contact between the diversion resistor and the over-temperature sense wire resulted in high voltage being fed into the central controller PC board. Examination of the controller showed clear HV damage: to an opto-isolator, various burn marks were on the board, and material ejected from over-current devices (Figure 11).

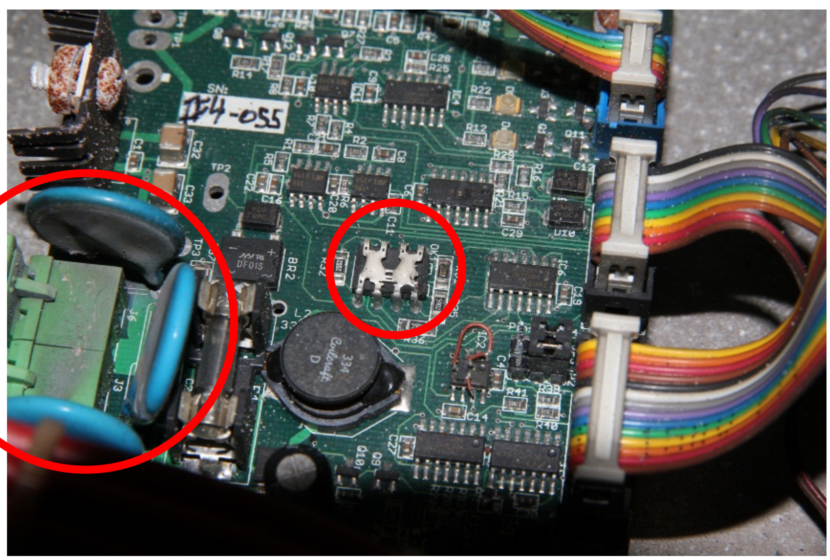

Figure 11. Damaged controller board
(*Photo by Lee Jay Fingersh, NREL*)

The optical coupler in the center of Figure 11 is used to detect the state of the diversion load thermal switches. It had its top blown off. The transient absorber (on the left) caused a burn mark on the green connector below it.

2. Brake Control Disabled

The two diversion load thermal switches are wired in series with a normally open relay in the controller that supplies power to the up-tower normally closed brake contactor (Figure 12). Two bipolar transistors are also included in the relay control loop. They allow brake operation by the turbine controller microcomputer and the E-Stop button. Unfortunately, when HV made contact with the diversion load temperature sense wiring, it most likely caused these transistors to fail in the “on” state. The result was that the up-tower brake could not engage, despite a pending over-speed condition. For the same reason, the brake would not engage when the E-Stop button was pressed.

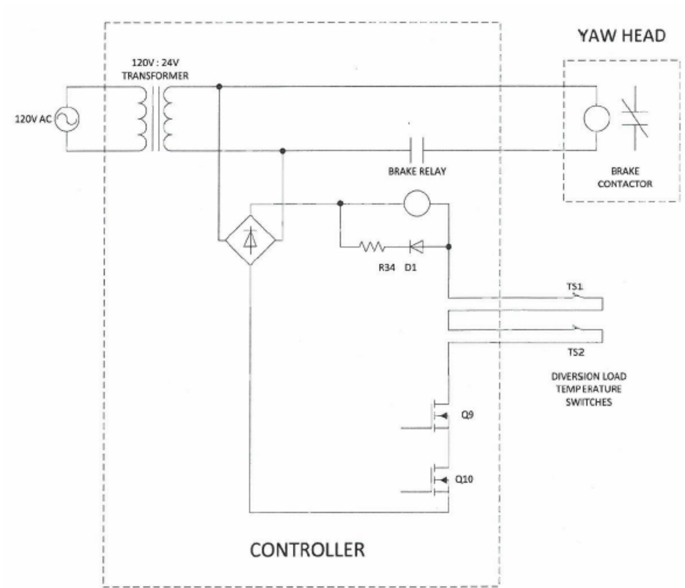

Figure 12. Simplified turbine brake control schematic

(*Diagram from Xzeres internal report*)

3. Diversion Load Control Disabled

The HV input to the controller blew power supply fuses and the controller stopped working. Turbine speed control and bus voltage regulation failed as the diversion load control stopped switching.

4. Turbine Rpm Increases, Inverters Shut Down

Without the diversion loads consuming power to control speed and bus voltage, turbine rpm increased, and DC bus voltage exceeded 600 V. This caused the SMA inverters to shut down, removing all load from the turbine.

5. Unloaded Turbine Generates 800+ VDC

The unloaded turbine generated voltages in excess of 800 VDC. This caused electrolytic capacitors in the turbine controller and inverter to fail (Figure 13).

Figure 13. Capacitor failure in the turbine controller (left) and inverters (right)
(*Left photo by Rob Wills, Intergrid, LLC, right photo by Lee Jay Fingersh, NREL*)

This failure spread conductive material over the rectifier and load chopper boards, causing them to fail.

6. Diversion Load IGBT Switches Fail Shorted

This failure caused the diversion loads to glow red hot, as observed by the owner. Diversion loads were then absorbing full turbine power, perhaps greater than 20 kW total. The upper diversion load terminal block failed due to current and operating temperature.

7. High Currents Flow in Diversion Controllers and Turbine Windings

The controller rectifiers and/or chopper diodes failed. High current flowed through the turbine alternator windings. The controller PC board failed.

8. Turbine Windings Overheat and Short Internally

High alternator currents caused the turbine stator to overheat. The alternator shorted internally, thereby reducing output voltage but increasing up-tower power dissipation.

9. Turbine Rotor Magnets Overheat

The turbine rotor magnets overheated and lost some of their magnetism. The combination of shorted windings and weakened magnets means that the up-tower electrical braking would be ineffective, even if activated.

10. Owner Operates E-Stop Button

This action had no effect, as the E-Stop control circuit had been damaged.

11. Owner Disables Power to Inverters

This action had no effect, as the inverters were already disabled due to high bus voltage.

12. Owner Operates Turbine Disconnect Switches

The owner operated the disconnect switches located outside the house and at the base of the turbine's tower. This action had no effect, as the alternator was already shorted, the disconnect switches did not have auxiliary contacts for the brake 24-V AC wires, and the electrical brake equipment up-tower was ineffective.

13. JBS Applies Short to Alternator Output

This step had no effect, as the alternator had already shorted and/or the magnets were weakened.

14. Turbine Emits Flame

The fire continued throughout the night, as stator winding varnish vaporized and burned. The investigators saw no evidence on the stator that heating and fire were caused by mechanical rubbing or disintegration of magnets in the alternator gap.

15. Turbine Spins for a Month

Wind conditions remained too high during the month to safely disable the turbine. The tail furling system and blades remained in serviceable condition during this time and the turbine remained mechanically intact.

This sequence of events agrees with the Xzeres internal analysis, although they did not mention magnet weakening. However, Xzeres did identify the likelihood of a shorted stator (Figure 14).

Figure 14. Alternator stator windings with the varnish burned off
(*Photo by Lee Jay Fingersh, NREL*)

Post-Installation Modifications

Apart from work that was conducted by an HVAC contractor near the diversion loads, there were no post-installation modifications to the turbine installation.

Ongoing Risk Versus an Isolated Incident

Isolated Incident

This was clearly an isolated incident that can and will be avoided in future installations. It is a simple matter to restrain low-voltage sense wiring to ensure that it cannot contact high-voltage components.

Evaluation of Ongoing Risk

The investigators consider the Villas turbine fire to be an isolated event caused by a combination of manufacturing design, installation, and (possibly) post-installation actions. There are currently about 160 ARE and Xzeres turbines operating worldwide and few have had problems. The ability of the turbine to spin without its normal electric braking controls and survive for a month is a testament to the redundant speed control mechanism (tail furling) and the blade design. We conclude that the ongoing risk of failure for this turbine, including the new manufacturing modifications, is very small.

Turbine Over-Speed and Electric Braking

The single most important protection function for a wind turbine is over-speed protection. This is because rotational speed in excess of design limits can result in mechanical failure and, in particular, blade failure and risk from flying debris.

Any properly designed wind turbine will use multiple, redundant means to ensure that a single fault will not result in mechanical failure, and that multiple simultaneous faults are unlikely and relatively benign.

The Xzeres 442 turbine uses several approaches to achieve this goal:

1. The auto-furling tail limits rotor speed by turning the rotor out of the wind in high wind conditions
2. Dual diversion loads and diversion load controllers to provide redundancy
3. The use of dual normally closed contactors for the up-tower brake

   Three separate brake resistors each connected line to Y-point (so a single resistor failure results in a 33% brake loss rather than 50% for a delta connection).

The Xzeres 442 also attempts to detect *dormant* faults by testing for diversion load and up-tower brake control on every turbine start.

The overall speed control philosophy is:

1. The bulk of the turbine energy is absorbed electrically by the inverters (12 kW rating)
2. Additional energy is absorbed by the dual-redundant diversion loads (18 kW peak rating)
3. A system fault, diversion load over-temperature, disconnect actuation, or E-Stop will bring the turbine to an idle state by connecting brake-resistors up-tower to the alternator
4. If all else fails, the furling turbine tail will moderate rotor speed.

Electric braking is relied upon for the above cases 1–3. With appropriate design, electric braking can be a safe and reliable means for speed control. There are, however, some situations where electric braking can fail, including magnet weakening (as proposed by the investigators as a contributing factor to this incident), and excessive alternator inductance and rpm. Alternator frequency is proportional to rpm and braking current is limited by stator inductive reactance, which is a function of frequency. If the rpm (and hence frequency) and alternator inductance are high enough, there will not be enough braking torque to counter blade torque and slow the turbine. Under either of these conditions, the turbine may fail to be braked electrically.

The Need to Educate First Responders

As part of the investigation, we interviewed Richard Harron Jr., fire chief for the town of Villas, New Jersey. He was one of the first to arrive at the scene on January 8, 2011. His actions upon arrival were to evacuate the house, call the local utility (Atlantic City Electric) to have the utility power disconnected and position firemen in the garage to monitor equipment, and to make sure that the fire did not spread. Chief Harron commented on the noise that the turbine was making and his view that the rotor was "spinning freely."

Chief Harron made it clear that first responders need training about wind and solar energy systems. Two of our recommendations relate to first responders: that shutdown procedures for a turbine should be posted in appropriate locations and that training materials should be developed.

Turbine fires are very rare. The most likely occurrence is a fire at a residence with an attached, operating wind turbine. In this circumstance, a firefighter needs to know how to disable the wind turbine so that it ceases to be a potentially hazardous source of electricity in the attached building.

Conclusions and Recommendations

As a result of the work conducted, the investigators make the following six recommendations:

1. **Allow Installation of Xzeres 442 Wind Turbines in New Jersey.** The incident in Villas, New Jersey, last year was an isolated event that is unlikely to occur again. The Xzeres 442 turbine, now modified, is a reliable, efficient unit that is very unlikely to experience similar problems. The Xzeres 422 has been certified by the United Kingdom's Microgeneration Certification Scheme, and has been given conditional temporary certification by the U.S. Small Wind Certification Council (SWCC) to the BWEA/AWEA 9.1-2009 Standard as of November 17, 2011.
2. **Make Improvements at the Present Villas 442 Site.** The diversion loads should be installed according to the manufacturer's instructions (side by side with the specified clearances), or otherwise as directed by Xzeres if space does not allow side-by-side mounting.
3. **Make Improvements to the Xzeres 442 Turbine**. As a result of our review, we suggest the following items to help improve the reliability of the turbine. These items do not need to be implemented now, or on the whole fleet of installed turbines, they are simply suggestions for product development and improvement:
    a. Use heavier crimp terminals for up-tower brake wiring such as strain relieve wiring with heat shrink tubing. Or, use a similar method over terminal barrels.
    b. Use a larger terminal block for the diversion loads. The failure of the terminal block on the upper load did not contribute to the Villas incident, but the diversion loads are important to safe operation, and a small investment here will increase reliability.
    c. Clarify in the installation manual that the diversion loads should be mounted *horizontally* side by side—by emphasizing the text and including a drawing of the complete equipment setup.
    d. Add a pole to the E-Stop switch that opens the 24 VAC supply to the up-tower brake contactor directly, rather than relying on electronics to serve this purpose.
    e. Consider including circuitry in the nacelle (possibly a relay with passive components, or an SCR circuit) to engage the up-tower brake in the event of turbine over-speed or over-voltage. By doing so, the up-tower brake will engage even if the turbine output conductors are severed, or if a control failure occurs (similar to the incident in Villas).
4. **Inspect Other ARE and Xzeres 442 Installations for Potential Problems**. It would be prudent for Xzeres installers and/or owners to inspect the complete fleet of existing ARE and Xzeres 442 installations to ensure that this diversion load wiring problem does not occur at another site. Xzeres could develop a simple field retrofit kit consisting of clamps and self-drilling sheet metal screws. In addition, installations should be checked to make sure that all turbine disconnect switches have the brake interlock kits properly installed. All Model 442 installations in New Jersey should be required to be inspected for these two issues in order to receive rebates. Update: Xzeres reports that this recommendation was accepted and completed for all systems in the field by Xzeres staff and dealers. JBS

Solar and Wind also report that they have retrofitted all of their Xzeres installations as of February 2012.

5. **Adopt UL6142 Requirements for Small Wind Turbine Listing**. Underwriters Laboratories and an industry working group have recently ratified a standard for small wind turbine safety. It is an ANSI/UL Standard UL6142 [Underwriters Laboratories (undated)]. This new standard pays particular attention to E-Stop operation as well as the means for reliable over-speed prevention. It will be some time before the standard is published, and manufacturers will need a reasonable amount of time to complete certification. A requirement that small wind turbines be listed to UL6142 should not be required for at least a year or more and existing installations should be "grandfathered" in.

6. **Shutdown Procedure to be Posted.** At the recent National Electrical Code (NEC) meeting on proposals for the 2014 NEC, Dr. Wills proposed that the following requirement be added to Article 694 *Small Wind Electric Systems*:

   924.23(B) Shutdown Procedure. The shutdown procedure for a wind turbine shall be defined and permanently posted at the location of a shutdown means, and at the location of the turbine controller or disconnect, if different.

We recommend that this or similar language be included in future New Jersey turbine installation requirements.

7. **Training of First Responders**. A one-page fact sheet about small wind turbines should be prepared for first responders such as police officers and fire fighters.

Key points to be made should include the following:

a. Shutdown procedures will be posted at the shutdown means and at the location of the turbine controller. These should be followed in the event of a fire at a wind turbine site.

b. Wind electric systems are different from solar electric systems in the sense that it IS possible to disable the power source.

c. Cutting wind turbine output cables may cause a turbine to become uncontrolled. Follow shutdown procedures where possible.

d. If a turbine is running uncontrolled, keep responders and others away as blade failure could occur.

e. A runaway turbine can have four times the normal voltage on its output cables and potentially cause other problems. Be on the lookout for associated equipment and wiring failures.

References

ANSI/UL6142 Small Wind Turbine Systems (undated). *Underwriters Laboratories*. Adopted by Standards Technology Panel, January 2012. Date of publication currently unknown.

American Wind Energy Association (AWEA). AWEA 9.1-2009. AWEA Small Wind Turbine Performance and Safety Standard.

BWEA Small Wind Turbine Performance and Safety Standard.

International Electrotechnical Commission (IEC). IEC 61400-2 Design requirements for small wind turbines.

van Dam, J. and Jager, D. (2010). *Wind Turbine Generator System Power Performance Test Report for the ARE442 Wind Turbine*. NREL Technical Report TP-500-46191.

United States National Electrical Code (NEC). NFPA 70. *National Fire Protection Association*. New Jersey currently uses the 2008 edition, effective 4/6/2009. They will likely adopt the 2011 code in April 2012.

The following documents were supplied under a nondisclosure agreement from Xzeres Corporation to Dr. Wills:

Schematic diagrams for the controller, diversion load controller, indicator LEDs, rectifier, and other controller PCBs.

Photographs of the failed diversion load wiring, and another of changes made to new production

Assembly drawings for diversion load showing additional wire restraints, dated Jan 20, 2011.

Manufacturing Change Order (January 20, 2011). Documenting changes to diversion load wiring.

Xzeres. (2010). The XZERES 442 GRID-CONNECT WIND ENERGY SYSTEM Installation and Operation Manual, Rev C.

Xzeres. (undated). Hasson Turbine Failure Investigation Report. Internal report.