The Impact of the April 27, 2011 Severe Weather Outbreak on TVA's Radiological Emergency Preparedness Program

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Abstract

On April 27, 2011, the Southeast United States endured an historic outbreak of severe weather that produced a record-breaking number of tornadoes, among numerous other high wind and hail reports. This outbreak surpassed the 1974 outbreak in many statistics and was the deadliest tornado outbreak in our region since 1932. Over 100 tornados were reported in the TVA service territory, several of which were long-track, high intensity.

As several rounds of severe weather traversed the TVA region that day, tornado warnings were issued multiple times for each of TVA's three operating nuclear plants and the corporate emergency centers. One such warning was for a violent, EF-5 tornado that passed within 5 miles of the Browns Ferry Nuclear (BFN) Plant in North Alabama, causing a 3-unit SCRAM and subsequent Notice of Unusual Event (NOUE) to the Nuclear Regulatory Commission (NRC).

The Central Emergency Control Center (CECC) was activated in support of the BFN event, and meteorological support was provided both from the main CECC in Chattanooga, TN and a satellite location in Muscle Shoals, AL.

This paper and presentation will provide an overview of the event, the support that the CECC Meteorologists provided during and after the event, and lessons learned.

Introduction

For more than seven decades, the Tennessee Valley Authority (TVA) has provided affordable electricity, environmental stewardship and economic development opportunities in the Tennessee Valley region. TVA was established by Congress in 1933 to address a wide range of environmental, economic and technological issues, including the need for low-cost electricity and navigation and flood control along the Tennessee River system.

TVA's power service territory includes most of Tennessee and parts of Alabama, Georgia, Kentucky, Mississippi, North Carolina and Virginia, covering 80,000 square miles (see Figure 1) and providing electricity to more than 9 million people. TVA sells electricity to 155 local power companies and 57 directly served industries and federal facilities.

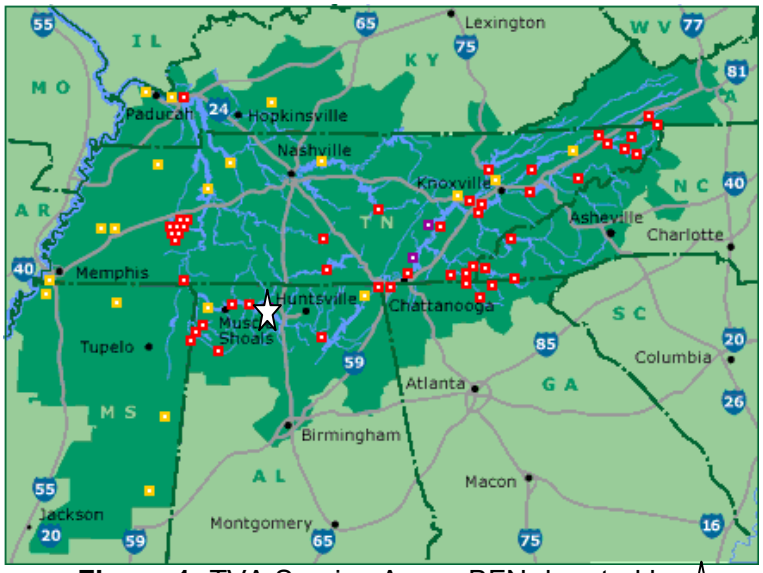

Figure 1: TVA Service Area - BFN denoted by ☆

TVA's first nuclear plant, Browns Ferry, is located on 840 acres beside Wheeler Reservoir on the Tennessee River, near Athens, Alabama. Browns Ferry's three boiling water reactors have a maximum capacity of some 3,300 megawatts, which is about 10 percent of TVA's total generation capacity.

April 27, 2011 Event

Overview

On April 27, 2011, the Southeast US endured an historic outbreak of severe weather that produced a record-breaking number of tornadoes, among numerous other high wind and hail reports. This outbreak surpassed the 1974 outbreak in many statistics and was the deadliest tornado outbreak in our region since 1932.

This massive storm destroyed large portions of the TVA transmission system in MS and AL and left localized damage in TN. More than 100 tornados were reported in the TVA service territory, several of which were long-track tornados of EF-4 and EF-5 intensity. At the peak of the storm, over 3,000 MW of load at 125 substations and 107 transmission lines were interrupted, serving approximately 850,000 customers; and

5,300 MW of generation was lost. In the wake of the massive storm 353 transmission structures were left damaged or destroyed. TVA's Central Emergency Control Center (CECC) activated to support the 3 Unit SCRAM (insertion of control rods to halt nuclear reaction), and subsequent Notice of Unusual Event (NOUE) at Browns Ferry Nuclear (BFN) Plant in North AL.

TVA Meteorological Data

At the time of the April 27, 2011 event, TVA's Atmospheric Modeling & Monitoring Group had a procedure in place to issue "Inclement Weather Forecasts" when certain severe or winter weather criteria were met. The initial forecast for this event was issued two days in advance, April 25, and warned of a Moderate Risk of a significant severe weather outbreak across the Tennessee Valley region. Subsequent forecasts were issued as the risks were upgraded, with the last forecast issued the morning of the outbreak.

Three distinct rounds of severe storms traversed the TN Valley region and more specifically the North AL area during the day. The first line of severe storms moved through in the early morning hours between 0200-0800 CDT. The second line moved through in the late morning - early afternoon hours between 0800-1400 CDT. The third round of severe weather was less linear in structure and contained devastating supercells, beginning around 1400 CDT and lasting through the evening.

Within these rounds of severe weather, multiple tornado warnings were issued for all of TVA's nuclear sites, several corporate sites, and numerous other TVA sites and interests. The meteorological tower at BFN samples temperature and wind speed and direction at three levels, 10 meters, 46 meters and 91 meters. Stability class information is derived from the temperature data. Dewpoint is sampled on a separate 10 meter tower and solar radiation and rainfall are measured at ground level. Data from this site clearly display multiple storms passing over or near the BFN area during all three rounds of severe weather (as seen in Figure 2).

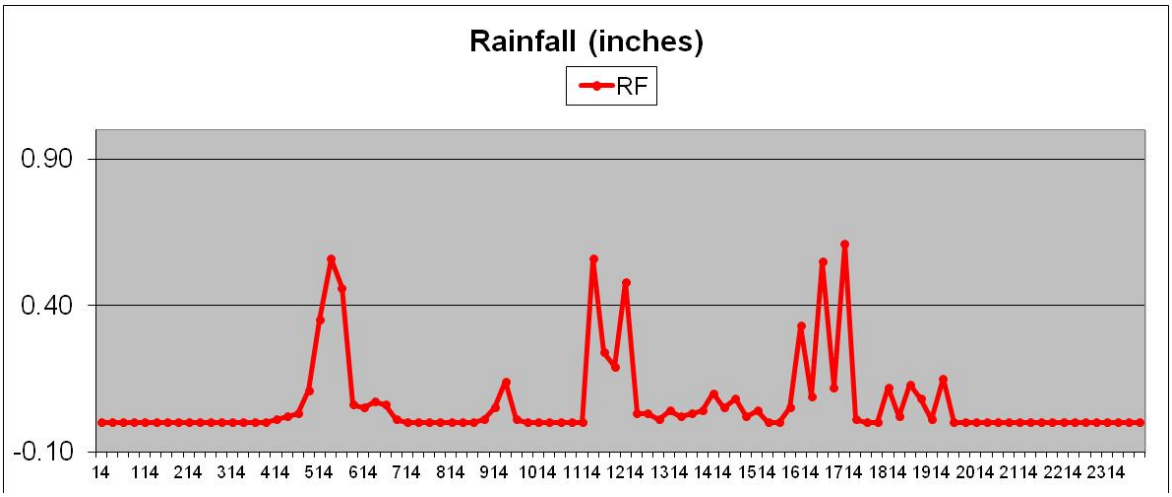

Figure 2: Rainfall recorded at BFN 0100-2400 April 27, 2011

The EF-5 tornado that tracked over 100 miles across North Alabama and into South Tennessee passed within 5 miles to the East-Southeast of BFN shortly after 1600 CDT. The BFN meteorological tower 46 meter & 91 meter sonic wind sensors were non-responsive after 1612; however, the 10 meter sonic recorded wind speeds nearing 60 miles per hour approximately 1615 and again approximately 1715 (Figure 3).

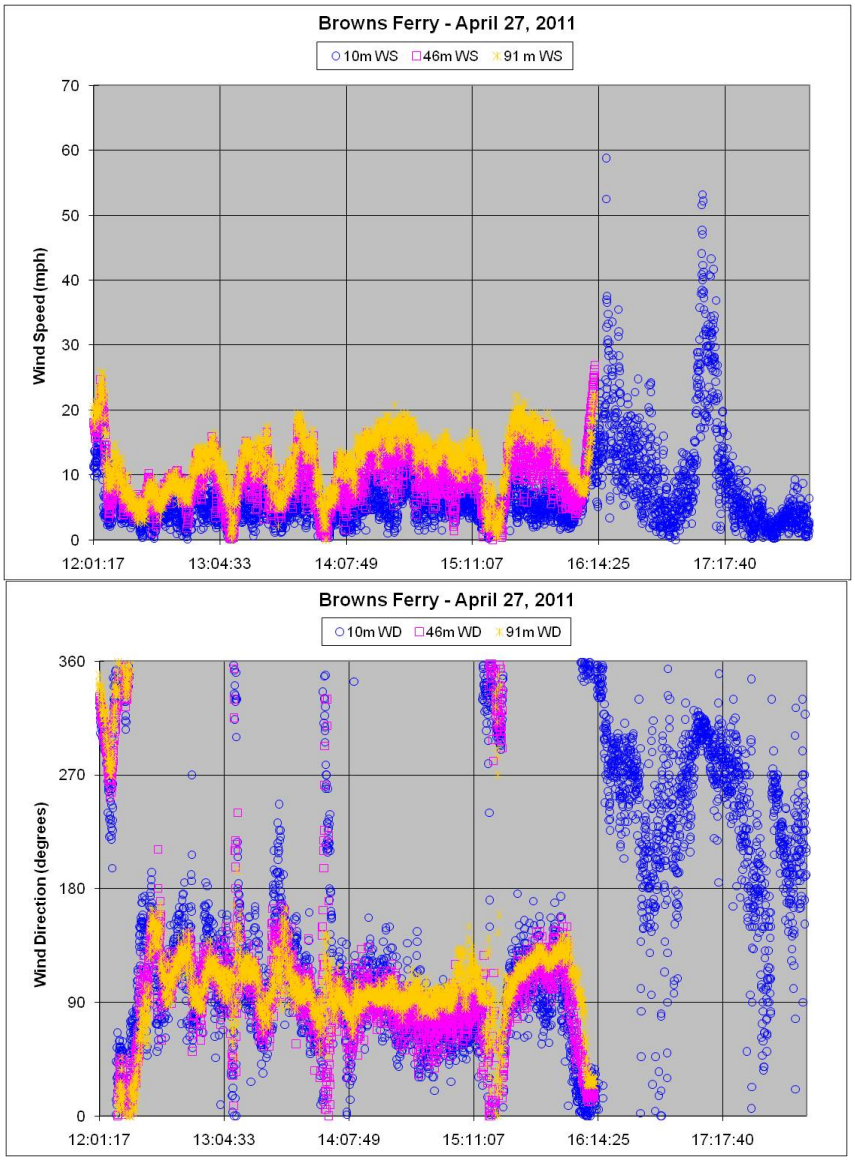

Figure 3: BFN 5-sec Sonic Wind Data 1200-1800 CDT April 27, 2011

BFN NOUE

BFN has eight Emergency Diesel Generators (EDGs) on site for backup power in the event of the loss of off-site power. On April 24, 2011 one of the eight EDGs was taken out of service for a maintenance outage.

As discussed previously, several rounds of severe weather impacted the site, with the earliest tornado warnings and high wind alarms experienced around 0452 & 0912 CDT the morning of April 27th. Later in the morning, between 1038-1217 CDT, storm

damage to the electrical grid caused an urgent load reduction on BFN Unit 2 and a brief Limited Condition of Operation (LCO) due to the loss of one 161kV line coming into the plant. Another tornado warning was issued for the BFN area around 1401, and shortly after this storm passed 23 (out of 100) emergency sirens were not reporting. Between 1500-1600 CDT, a transmission alert was issued due to large area system damage, BFN lost communication systems and the first 500kV line coming into the plant. At 1610, all corporate links to BFN were lost, including communication with the meteorological tower shortly after. Approximately 1617 the EF-5 tornado that tracked over 100 miles across North Alabama and into South Tennessee passed within 5 miles to the East-Southeast of BFN. Consequently, all remaining 500kV lines and all but one 161kV line into the plant were lost. Unit 1 reduced power in an attempt to stabilize the grid; however this effort was unsuccessful and all three units experienced a SCRAM (or reactor trip), and the seven available EDGs began operating. Figure 4 displays a portion of the tornado's path relative to BFN and the 500kV connection points.

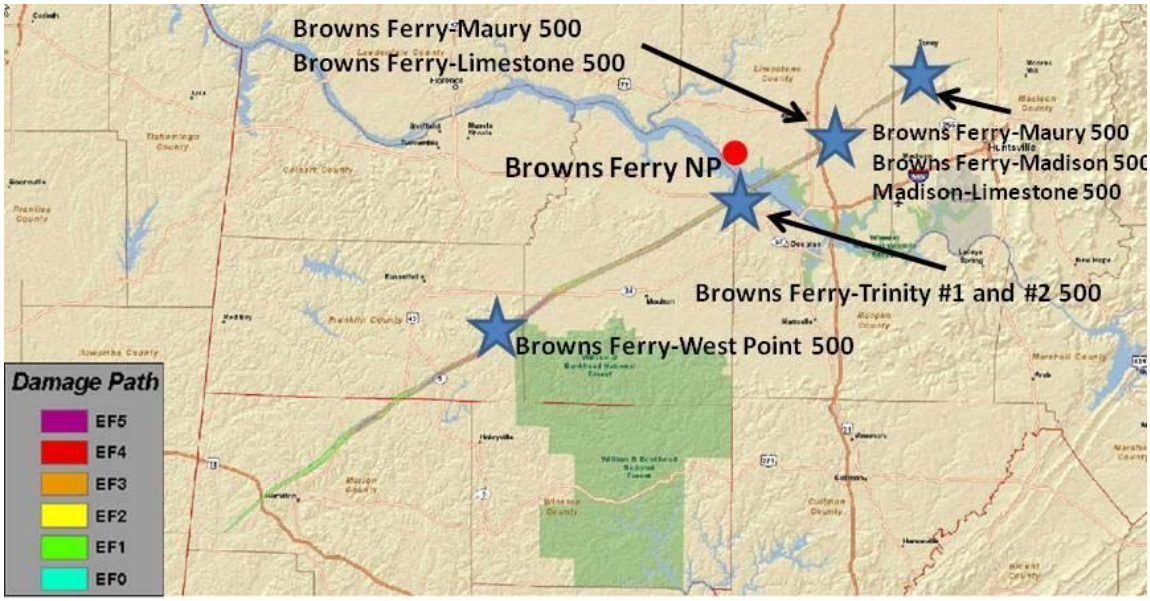

Figure 4: BFN EF-5 Tornado Track Relative to Site & 500kV Connection Points

At 1674 CDT TVA's CECC activated and the NOUE was declared at 1701 based on EDGs supplying power to the shutdown boards for a time period greater than 15 minutes. It was also noted that only 12 out of 100 BFN sirens were operational due to four being destroyed and the remainder being without power. Seventy sirens is the minimum required operational at any given time. When the CECC first activated, meteorological staff initially responded to the Muscle Shoals, AL Weather Center (essentially an extension of the CECC) until a meteorologist could report to the Chattanooga, TN CECC location. Initially there was no communication with the meteorological tower; therefore, all data was based on Huntsville National Weather Service observations. During this time frame, other supercells, many associated with tornado warnings, were impacting other TVA locations. One such storm caused a tornado warning to be issued for Chattanooga, TN at 1750 CDT. The CECC is located on the 6th floor of a TVA office building downtown. At 1803, the CECC was forced to evacuate. After the all-clear, the facility was re-staffed at 1913, only to be re-evacuated at 2027 for a second tornado warning. At 2114 the CECC resumed normal operations, with meteorological support in Chattanooga.

A few hours after initial staffing, meteorological data was manually retrieved from the tower and communicated to the CECC, and 91 and 46 meter winds were “Nowcast” based on the 10 meter winds using TVA’s Nowcast Manual for BFN.

The first shift relief was scheduled to report in the early morning hours of April 28th, with meteorological staff again reporting to the Muscle Shoals location. However, upon arrival in Muscle Shoals, power in the building was unreliable and the Weather Center was not on back-up power at that time. Round the clock coverage continued through 0940 CDT April 28th, at which time meteorological support was placed on standby for the duration of the NOUE.

TVA Damage & Restoration

Only one 161kV line remained energized and in service to BFN during the entire storm event and restoration. This was the sole connection between BFN and the transmission system; and for that reason was deemed most critical during restoration activities, and actions were taken to protect it. It was not until May 1st that a second 161kV line was restored to the plant. Restoration priorities in Alabama included restoring off-site power to BFN and establishing a power source to critical loads such as hospitals.

For 20 hours and 34 minutes on April 27-28, Guntersville Hydro plant was the TVA power system in Northeast Alabama, creating an “island” of power. “Blackstart” procedures were implemented using this plant to begin restoration to the grid. These procedures are practiced annually, but rarely if ever used. A diesel generator provides power to the plant to open a wicket gate, allowing the flow of water to spin the turbines and drive the main generators. Slowly as the four units were placed back in service, lines across North Alabama began the process of re-energizing. At 1645 on April 28th TVA reconnected Guntersville to Widows Creek Fossil Plant and Guntersville was no longer the only source of power in the area.

Sufficient offsite power to discontinue the use of EDGs was restored to BFN approximately 2010 on May 2, 2011, and the NOUE was terminated shortly after at 2050 CDT. By May 4th, 98 percent of customer delivery points were restored with only 25 percent of the structures & 40 percent of the lines repaired. The BFN 500kV switchyard was re-energized May 13th.

Corrective Actions

Why - Once in a Lifetime?

The BFN Final Safety Analysis Report discusses tornado frequency and recurrence intervals for the site. Based on two different analyses, it states that the mean recurrence interval for a tornado to impact the site is between 600 and 1,433 years.

Given these statistics, one might assume the site would have a reasonable chance of not experiencing another strong tornado nearby for several years. However, less than one year later, on March 2, 2012, several tornadoes touched down in North Alabama. An EF-3 was responsible for damage just a few miles northeast of BFN in the same county. In fact, several miles of this track nearly over-lapped with the EF-5 track the year previous and caused extensive damage to many of the same areas. Thankfully, BFN

was not directly impacted by this storm and the power grid remained stable. This did however, re-emphasize the need for several corrective actions related to the meteorological program.

Specific Actions

A total of 96 Problem Evaluation Reports (PERs) were issued due to the April 27, 2011 event; a handful of which dealt directly with meteorological support. TVA's Atmospheric Modeling & Monitoring (AM&M) Group established a standardized source of predictive weather for the Nuclear Power Group (NPG). NPG integrated the application of predictive weather products based upon weather thresholds relative to risk, and established action thresholds and protocols relative to risk due to weather for on-line and outage maintenance / modifications activities. NPG also performed a self assessment focusing on the application of predictive weather products and application to personnel risk from severe weather, and evaluated and implemented applicable warning protocols for impending periods of severe weather (provide advance information and briefings, etc.).

In order to satisfy these PERs, TVA's AM&M group now issues a daily forecast and distributes it to a wider audience than the previous inclement weather forecast distribution list. Inclement weather forecasts are still issued (in addition to the daily forecasts) as needed to elevate the visibility of important forecasts. Plant operations personnel now consult the on-duty meteorologist on the forecast (e.g. 14 day severe outlook) prior to placing critical equipment in outage (such as back-up EDGs).

Additional Lessons Learned

In order to address evacuations due to severe weather and power outages, the Muscle Shoals Weather Center was relocated to the basement & provided with a back-up power source. Similarly, a refuge location was established for the Chattanooga CECC so that operations can continue if relocated.

In response to the unprecedented event in which all NPG plants and corporate emergency response centers were impacted by the same threat, drill scenarios involving multiple plants impacted are in the near future. Emergency facilities have been re-designed to facilitate multiple plant events; and drill scenarios incorporating more unusual weather events are being implemented.

Finally, in the event that a meteorological tower is deemed inoperable and uninhabitable, meaning instrument personnel cannot work on-site or reach the tower, portable meteorological towers with stand alone power sources are being developed.

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TVA Document: Browns Ferry Event Report Notification of Unusual Event 04/27/2011

TVA Document: PER 364318 – Root Cause Analysis Report TVA Browns Ferry

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