Maintaining Regional Reliability During Expansion of the Maury 500-kV GIS Facility

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Abstract—Staged expansion of 500-kV GIS switchgear was completed at the Maury 500-kV Substation without impact to system performance based upon proper planning and execution of the work being performed.

I. BACKGROUND

The Tennessee Valley Authority (TVA) is a federally-owned corporation fulfilling a multi-faceted mission in the seven-state region of Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia. TVA provides electric power to the seven-state region as part of its overall mission. The middle Tennessee area represents one of the largest population centers in the TVA service area. TVA utilizes its 500-kV system for bulk power transmission, and typically delivers power to its distributors and direct-serve industrial customers from its 161-kV system. TVA operates the Maury 500-kV Substation in Maury County, Tennessee approximately 40 miles south of Nashville. This substation plays a substantial role in maintaining system reliability in the middle Tennessee area.

In 2005, TVA planning studies indicated that certain 500-kV substation facilities and 161-kV transmission lines in the middle Tennessee area would reach peak capacities by 2010. An evaluation of alternatives indicated the preferred solution to be constructing a new 500/161-kV substation (Rutherford 500-kV Substation) southeast of Nashville with an expanded Maury 500-kV substation serving as the 500-kV source. Rutherford 500-kV Substation would be radially served from the 500-kV system, being at the end of a 28 mile 500-kV transmission line from the Maury 500-kV Substation. The project would also require the construction of 36 miles of new 161-kV transmission lines. The required in-service-date for the new facility was established to be June 1, 2010.

II. MAURY 500-KV SUBSTATION EXPANSION

The Maury 500-kV Substation utilizes 500-kV Gas Insulated Switchgear (GIS) due to site constraints. Site modifications that increase the overall footprint of the facility result in a substantial project cost due to the topography and geology of the site. The facility is located in sloping terrain underlain by a limestone deposit. Thus site modifications to

increase the station foot print result in large amounts of rock removal. Measures that have been undertaken thus far during the life of the station include constructing the yard on three distinct elevation levels to minimize rock removal as well as utilization of GIS to minimize the required footprint.

Prior to the expansion, Maury 500-kV Substation utilized a 4 position GIS ring bus breaker configuration with buses in a Bus 1/Bus 2 arrangement. The 500-kV circuit breakers utilized at Maury 500-kV Substation have a rated continuous current rating of 3000 A and a rated interrupting current of 50 kA. The GIS switchgear is enclosed in a building with environmental controls that was sized to allow room for future expansion of the GIS switchgear after the initial construction.

The Maury 500-kV Substation served as the terminus of three 500-kV circuits prior to its expansion to accommodate the Rutherford 500-kV substation. The Maury 500-kV Substation has a direct connection to a nuclear generating facility and two other 500-kV substations, being Davidson 500-kV Substation and Franklin 500-kV Substation. The Franklin 500-kV Substation is directly connected to a second nuclear generating facility. Thus outage-related activities on the Maury 500-kV system must be coordinated with two nuclear generation facilities. Given the impact to nuclear generation facilities, as well as the impact to reliability of the region, all work at the site during the expansion was planned and implemented with outage scheduling and reliability of foremost importance.

It was determined for operational and reliability reasons to convert the ring bus configuration to a breaker-and-a-half scheme. To accommodate the new 500-kV transmission line for the Rutherford 500-kV Substation and convert the ring bus to a breaker and a half scheme, a new diameter was added to the existing switch gear and adding two breaker bays in an existing diameter as shown in Figure 1. Additional work at the site as part of the overall expansion project included installation of external facilities necessary for a new line terminus including expanding the foot print of the yard, grounding for the expanded yard, a pull-off structure for the conductor termination, as well as conventional air insulated

rigid bus work and supports. Protective relays and controls were also modernized as part of the project.

effort was crucial to the success of the project in being able to obtain outages and minimize sensitive activities that could impact system reliability during times of heavy loading on the system.

IV. SITE PREPARATION

An expanded yard was required in order to terminate a new 500-kV transmission line into the Maury 500-kV Substation. Expansion of the yard required removal of 25,000 cubic yards of rock. The rock was undercut 3 feet in order to provide a layer of earth material for grounding. 3,500 cubic yards of earth were placed in the expanded yard.

The rock removal and site preparation was performed during summer months of 2008, allowing the site to be ready for the electrical installations in fall and spring, taking advantage of seasonal outage availability. Energized equipment including conventional air insulated as well as GIS equipment was located in the immediate proximity of the rock removal operations. Due to these concerns, conventional blasting was not utilized during the rock removal efforts in order to minimize the risk of damaging the equipment at the station or causing an interruption of the system during the heavily loaded summer months. Conventional hydraulic hammering rams were utilized for rock removal at this site. The hammers were mounted on tracked hydraulic excavators and the expanded footprint was carved from the rock. This approach prevented damage to the station facilities as well as system interruptions due to vibrations of large blasts.

Upon removing rock to the necessary slopes and grades, compacted earth was placed as a base for the yard expansion. The pull-off and conventional bus structures were founded in sound rock beneath the compacted earth. The portion of the GIS bus work that extended from the enclosed building into the yard was founded on the compacted earth with spread footings.

V. GIS INSTALLATION

The next phase of work at the Maury 500-kV Substation was the actual installation of the GIS equipment itself. Given the highly specialized nature of GIS equipment, the GIS manufacturer provided the installation of the equipment, local control cabinets, and terminations from the equipment into that control cabinet through its subcontractor as part of the equipment contract with TVA. The GIS manufacturer provided a factory representative to oversee the installation and check-out for the GIS equipment within its contract. Control cabling and terminations from the local control cabinet to the local and SCADA control systems were the responsibility of TVA. High-potential testing was performed on the GIS equipment as part of the GIS installation by the manufacturer prior to energizing any new or modified GIS equipment. TVA also performed its own checkout and testing.

Installation of the new GIS Switchgear required carefully coordinated outages and detailed planning in order to accomplish the task safely and successfully. In order to maintain stability of the region and the bulk system, the conversion of the ring bus to a breaker-and-a-half scheme was

Figure 1: Overview of Maury 500-kV GIS Expansion

III. SCHEDULE

It was determined in the planning stages of the project process that the GIS equipment would be installed early in the construction of the project prior to the planned protection and control modifications being performed. Thus a breaker-and-half scheme was installed and energized with a protection and control scheme for a ring bus configuration in operation. This decision was made based upon concern over the ability to secure 500-kV transmission line and transformer bank outages during the project construction period. Since the outages are most available in the spring and fall seasons, additional outage windows would be available to the project in the event outages were not available. This also provided a schedule buffer in the event that difficulties were encountered during the GIS manufacturing process that otherwise could have impacted the project schedule.

Based upon the GIS installation scheduling philosophy, GIS installation occurred during the spring months of calendar year 2009. With this as the schedule driver, predecessor and successor activities were determined and scheduled so that the modifications and testing would be completed in time for a June 01, 2010 in-service date. As a result, site preparation occurred during the summer and fall months of calendar year 2008 in order to have the site readied for installation of the GIS. Protection and control modifications occurred subsequent to the GIS installation, with outages in the fall months of 2009 and spring months of 2010. The scheduling

performed in two stages. During the first stage of the installation, the 500/161-kV transformer bank was taken out of service to provide a safe electrical clearance boundary for installation of the new GIS bus and switchgear. During the second stage, two connecting 500-kV transmission lines were removed from service in order to establish a safe electrical clearance boundary. The total outage time for installation of the GIS equipment was 55 calendar days during spring 2009.

The majority of the new GIS switchgear was installed during the first stage of installation. As shown in Figure 2, an electrical clearance boundary was established at each breaker around the transformer bank. This allowed the existing bus to be extended to so that most of the new GIS equipment could be installed. The duration of the transformer outage was 37 calendar days in March/April 2009. During this time, the new GIS switchgear was installed and connected to the existing GIS switchgear. Upon successful completion of all testing and checkout for this portion of the work, the equipment was energized and a new clearance boundary was established for the next work stage.

Figure 2: Maury 500-kV Substation Stage 1 GIS Equipment Installation

During Stage 2, the electrical clearance boundary was established around the Maury-Franklin 500-kV transmission line. As shown in Figure 3, this clearance allowed the transformer bank and the other two 500-kV transmission lines to remain in service while the installation continued. The duration of this outage was 18 calendar days in May 2009. During this time, the remaining new GIS switchgear was installed and connected to the existing recently completed GIS switchgear to create a breaker-and-a-half scheme for the Maury 500-kV Substation. Upon successful completion of all testing and checkout for this portion of the work, the equipment was energized.

Figure 3: Maury 500-kV Substation Stage 2 GIS Equipment Installation

As outlined in the original implementation plan, the breaker-and-a-half physical scheme would be completed prior to the modifications of the protection and control equipment for a breaker-and-a-half scheme. This configuration would be present for approximately nine months until the protection and control modifications were completed to allow the station to operate on a breaker-and-a-half scheme. To resolve this conflict, temporary alterations were implemented on the new GIS equipment that enabled the station to operate in a somewhat normal mode. These modifications consisted of closing the new breakers such that they essentially acted as a section of bus. Furthermore, the monitoring alarms for the new bus sections were temporarily wired into the alarms for the existing bus sections. Thus if alarms were received, it would require a bigger section of bus to be isolated and checked for the source of the alarm.

VI. CONCLUSION

The new Maury-Rutherford 500-kV transmission line was successfully energized on April 30, 2010, and began serving load on May 26, 2010. The expansion of the Maury 500-kV Substation was successful with regard to planning, scheduling, and execution whereby regional reliability was not jeopardized during the implementation of the work scope. The project was implemented safely with respect to personnel, equipment, and system reliability.