The 2008 Iowa Floods:
Structural Challenges and Solutions

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Abstract

Cedar Rapids, IA experienced an unprecedented flood of the Cedar River in June, 2008. The previous record flood was exceeded by over 11 feet, surpassing the 500-year flood zone in much of the city. Over 9.5 square miles of the city was directly affected. Two major generating plants, the central business district underground electric vaults, and over twenty substations were damaged and/or destroyed. Recovery and rebuilding the system required innovative solutions to emergency restoration of electrical power. This paper will describe the severity of the damage and detail the innovative solutions used to rebuild a key substation required to restore electric service to the city's downtown distribution network.

Background

Cedar Substation is located along the Cedar River in Cedar Rapids, IA. This substation included two 50 MVA transformers fed by three 34.5 kV lines and a metal clad switchgear comprised of two transformer mains, a bus tie, and nine 13.8 kV feeder circuits. The load served by Cedar Substation is primarily commercial and industrial. One feeder serves a heavy industrial customer with a load of approximately 15 MW, three feeders serve an underground network which supplies power to high density office and retail space in downtown Cedar Rapids. The remaining feeders serve industrial, commercial, and some residential loads adjacent to the downtown area.

On June 13th, 2008, the Cedar River crested 11 feet above the previous record flood level. Alliant Energy/IPL suffered the total loss of the 6th Street and Prairie Creek Stations, representing 380 MW of generating capacity, as well as the associated transmission and subtransmission substations at each plant. The flood waters also caused moderate to severe damage to 23 distribution substations and the complete destruction of Cedar Substation.

Cedar Substation was inundated with water after a heroic effort to sandbag the site. Water levels rose to the roof eaves of the 15 kV switchgear enclosure and inundated the control cabinets of both power transformers. It was clear that the substation would not be returned to service in its original form. The simultaneous loss of both generating stations, the 34.5 kV transmission system, and Cedar Substation resulted in the complete loss of power to downtown Cedar Rapids and a large area along both sides of the Cedar River. City hall, the police station, the county court house, the county jail, county administrative building, the county sheriff's office, 800 businesses and many hundreds of homes were blacked out. Both city hospitals were on emergency back-up generators. It was imperative to get power to this area to support the coming clean up and recovery efforts.

Substation Scope Development and Equipment Procurement

The planning group quickly realized the quickest way to restore power to the city center would be to build a temporary substation and connect it to the downtown underground network. They determined the new substation must have 50 MVA capacity with no fewer than eight distribution circuits. Planning also was working with the transmission service provider to find a way to re-energize at least one of the three 34.5 kV source lines to Cedar Substation to provide power to this substation.

On Sunday June 15th a substation team consisting of planners, substation engineers, and a construction manager was formed and given the task of siting, designing and building the Cedar Temporary Substation. Planning determined the temporary substation required a total of 50 MVA capacity and a minimum of eight 13.8 kV distribution feeders. Power would be delivered to the substation by an existing 34.5 kV subtransmission line. Armed with planning's requirements, the substation team put together a conceptual one-line (see figure 1a) and set up a scavenger team to hunt for suitable equipment which could be used to build the substation.

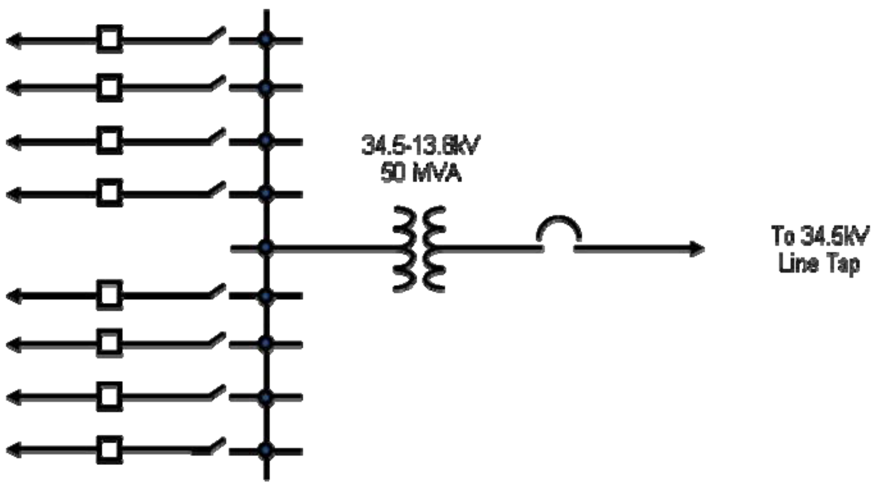

Figure 1a - Cedar Temporary Substation Conceptual One-Line

A spare 34.5-13.8 kV 50 MVA transformer purchased in 2004 as a back up to the original Cedar Substation transformers was stored in the regional operation center's material yard. This transformer was standing in four to five feet of mucky water at the crest, which partially flooded the control cabinet. The radiators were stored on the ground, completely inundated. All the bushings were missing, so an emergency purchase order was issued to buy replacements. Another order was placed to procure top and bottom connectors for the bushings.

Waukesha Electric Services was hired to clean the radiators, assemble and test the transformer, and check the control circuits. Fortunately, the transformer passed all tests, and the control circuits functioned normally after some cleaning.

The transformer was too large to fuse, so a circuit switcher was needed. We had taken delivery of a 69 kV circuit switcher for a new substation being built in north

Cedar Rapids. Unfortunately, this circuit switcher was submerged in flood waters and not serviceable. An emergency purchase order was issued, and a new circuit switcher arrived six days later.

This same substation was scheduled to receive a metal clad switchgear in mid-June. The switchgear comprised a 1200A main breaker, a 1200A bus tie breaker, 1200A bus, four 1200A distribution circuits, and associated relay panels. The switchgear alone met neither the 8 circuit nor the 50 MVA requirements.

A small rural substation was also being built in rural north central Iowa. Reviewing the material available from this project yielded a low tension dead end structure, a 69 kV gang operated switch, and a steel box structure comprising a transformer bay and three distribution bays. The bus conductor could support 50 MVA of load but the main disconnect switch was rated 2000A, slightly below the transformer's required full load current of 2091A at 13.8 kV. We debated whether the switch we had would be adequate, but this became a moot point when we salvaged two sets of 15 kV 3000A disconnect switches from yet another project.

On Tuesday, June 17th, two days after the water receded, the design team developed the one-line shown in Figure 1, along with an equipment plan and section views for the substation based on the available equipment. The design used the 69 kV switch and a 34.5 kV circuit switcher for primary side transformer protection. We could not locate a 15 kV 3000A circuit breaker in inventory, and lead times for new 15 kV breakers were unacceptably long. This forced us to connect the transformer secondary directly to the box structure bus through the 3000A disconnect switches installed on the transformer main bay. We installed reclosers on the three distribution circuits. Because all four bays of the box were used, we ran a flying tap conductor connecting the cross bus on top of the box structure to the roof bushings of the metal clad switchgear enclosure.

With three circuits coming off the box structure bus and four circuits coming off the switchgear bus, we were still one circuit short. A quick review of the switchgear drawings and a call to the manufacturer confirmed the bus tie position could be converted to a distribution circuit position in the field. This gave us the required eighth distribution circuit.

After consulting their load flow studies, planning was able to assign sufficient loads to the three recloser circuits to keep the remaining load current below the switchgear main breaker's 1200A continuous current rating. This arrangement allowed us to load the transformer to its 50 MVA top rating. Figure 1b shows the final equipment one-line defining the scope of the substation project.

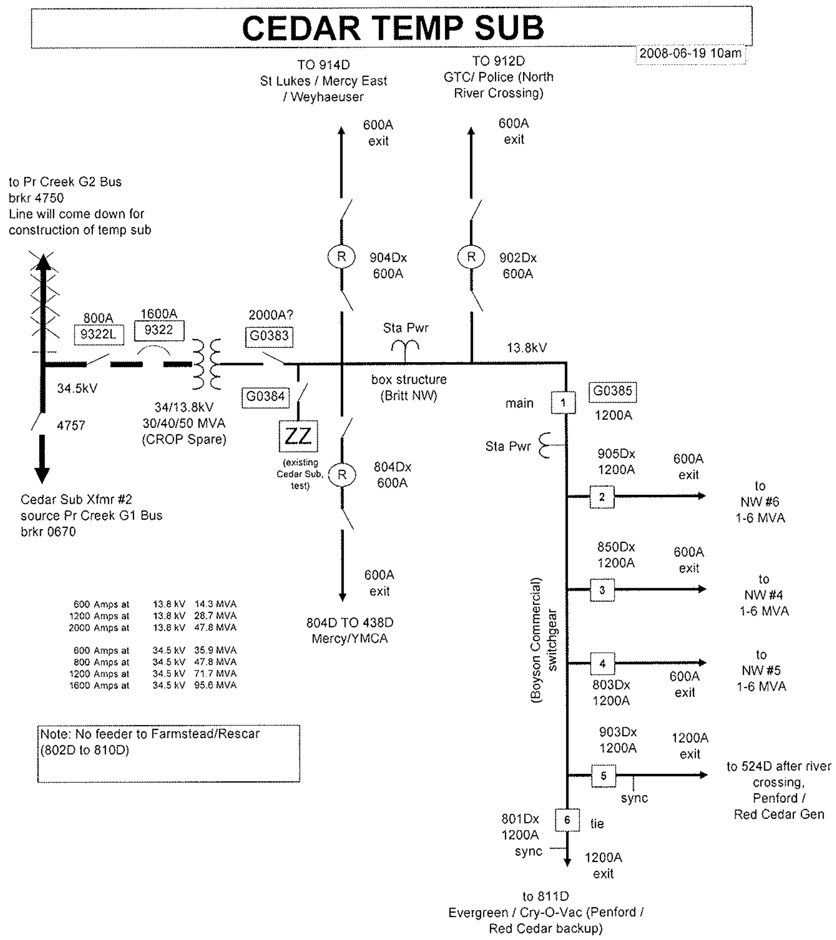

Figure 1b - Cedar Temporary Substation One-Line

Substation Siting and Contractor Mobilization

Also on June 17th, team members made their first site visit to find a location for the Cedar Temporary Substation. The area around the Cedar Substation is a municipal parking lot, consisting of a concrete surface broken up by landscaped islands that restricted the size of unobstructed areas. We chose an area in the parking lot adjacent to the flooded substation. This location was close to the existing feeder riser poles as well as the existing 34.5 kV lines tied to the flooded substation's subtransmission bus. Cedar Rapids officials were contacted and permission was given to build the substation on the chosen site.

Tim Terrell and Co., a local contractor, was hired to perform initial removal of flood debris from the site and to wash the area down to remove accumulated mud and sand deposited by the flood waters. Hooper Corporation, a utility construction company, was hired to supply labor and equipment for the construction of the substation. The Hooper substation crew demobilized from the construction project they were working on and mobilized to the site.

Foundation Layout and Details

The foundation designs, by necessity, were low-tech. We did not have time to remove the concrete parking surface, pour concrete pads, or drill and construct pier type foundations so we needed other options. Both our general office and our area maintenance facility were inaccessible due to the flood, which meant the tools available to lay out the equipment foundations were a 100 ft. cloth tape, a can of spray paint and our ingenuity.

We aligned the main bus with the transmission pole which would bring the source 34.5 kV line into the substation by eye and painted the bus center line on the concrete surface. Working from the equipment plan, we measured the center lines for the major structures and equipment, and painted the intersecting centers.

Transformer Foundation

At first glance, a parking lot surface looked level, but in fact the pavement sloped to drain surface water to the storm sewer inlets. Our first structural challenge was to devise a stable, level surface to set the power transformer on. We did not have the time to remove the existing concrete and pour a traditional concrete pad.

We considered setting the transformer on the concrete and shimming the base, but the amount of shims required resulted in an unacceptable stability risk. The contractor suggested building a gravel pad for the power transformer (see Figure 2). The pad was sized to extend about four ft. past the transformer base on all sides to provide a working surface after the transformer was set in place. A line of 8" high railroad ties was set next to the lower edge of the gravel pad. The ties served two purposes. First, to establish the pad thickness, and second, to prevent the road stone from washing away during heavy rains.

An 8 inch layer of gravel (crushed rock with fines typically used to build secondary roads in rural areas) was then laid directly on the concrete surface and compacted, starting at the ties and gradually tapering off up slope. This gave us the required level surface for the transformer. Gravel was chosen because it compacts well, thus giving us the desired stable surface.

Next, copperweld ground mats were laid on top of the base and bonded together to provide a ground plane. The ground mat array was then bonded to the substation ground grid. Finally, a 2" layer of top soil mixed with road stone was placed over the ground mats. This layer provided a measure of self-leveling as the weight of the transformer pressed down onto the pad.

The result of this design was more than satisfactory. After the transformer was set in place, we put a level on the transformer base and found all four sides were almost perfectly level.

Figure 2 - Road Stone Foundation for the Power Transformer

Switchgear Foundation

Our next structural challenge was to come up with a level surface to set the switchgear. Typically our standards call for an array of concrete piers to support a switchgear building, but we did not have time to bring in a drilling rig or pour and cure concrete for the necessary piers before the switchgear arrived on site.

We knew from the equipment plan that the back edge of the switchgear would overlap a curb delineating a landscaped island by about 12 inches. We could not compress the layout to avoid the overlap. This meant we not only had to deal with the slope of the concrete surface, but also had to compensate for the curb height when laying out the support system.

We used the typical footing arrangements from the drawings, and then eyeballed the approximate centerline of the temporary sub layout. We painted an extended substation centerline on the parking lot, then approximated an appropriate offset for the switchgear building centerline. Using this painted "spot" on the parking lot, we laid out the foundation pattern, painting the appropriate 'dots' on the concrete.

Wooden railroad ties were cut in half lengthwise, and each piece of wood tie was placed appropriately on each footing spot. Allowances were made for power and control cable exits. After the ties were in place, we checked the height differential between the ties and the top of the curb. We found the top of the curb was actually lower, and the height difference could be made up by simply placing more ties on top of the curb.

When the 68,000 lb switchgear was delivered and set into place (see Figure 3), workers were stationed at each tie to ensure solid contact at each footing location. As the building was slowly lowered onto the ties, the alignment was verified and the building came to rest evenly (miraculously) on all the ties. Only some minor shims under one corner of the structure were required to level the building. Out of curiosity, a worker put a level on the building's footing rail, and it was only a partial bubble off true level.

Figure 3 - Setting the 15kV Switchgear on Railroad Ties

Dead-End Tower Structure

Our third structural challenge was supporting a 30 ft. tall switch tower and associated 69kV disconnect switch. The incoming 34.5 kV line was a slack span which terminated on this structure. Even so, the structure was still subject to significant overturning moments due to its height.

The dead end tower was a two-leg design, with a bottom plate. No one knew how thick or strong the parking lot concrete was, so it was decided to design a steel base to widen the bearing surface for the structure. The base consisted of two parallel I-beams and a square plate. The plate was welded to the top flanges of the I-beams to form an H pattern. Mounting holes were punched in the plate to match the anchor bolt pattern of the tower leg bases. The lower flanges of the I-beams were punched to accommodate epoxy type anchor bolts set in the parking lot concrete surface. We contacted a local steel fabricator to properly size the steel members and manufacture the bases. Figures 4a to 4d show the completed steel base and details of the bolted connections.

Figure – 4a Dead-End Tower Base

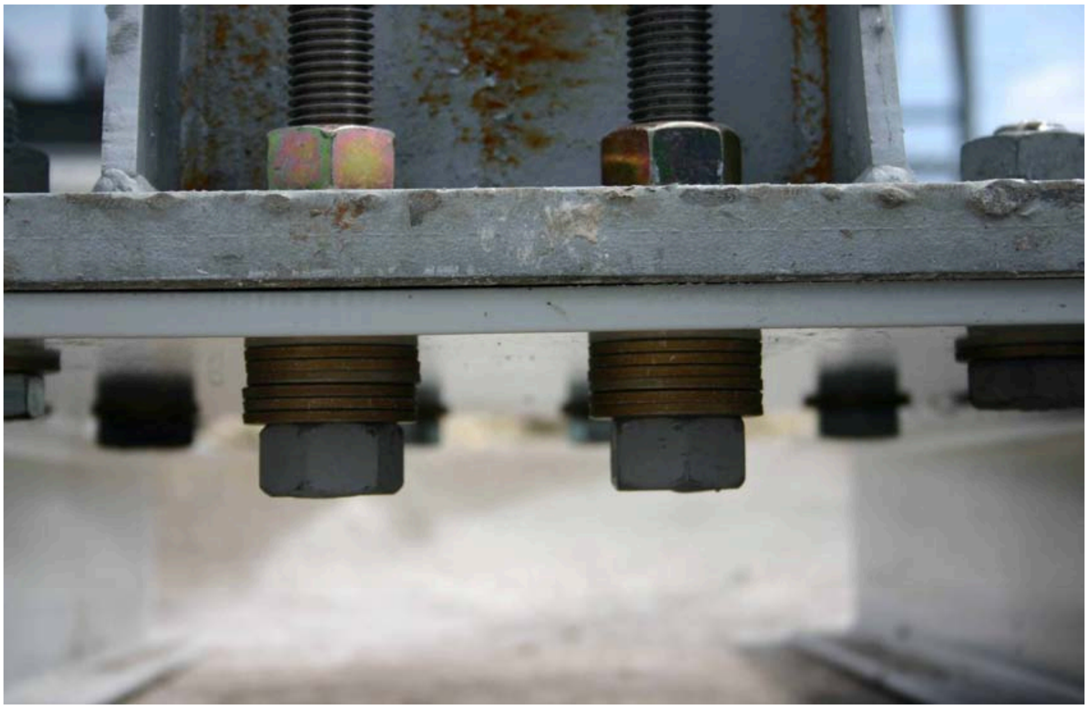

Figure 4b Dead-End Tower Bolted to Steel Base

Figure – 4c Steel Base Secured With Epoxy Anchors

Circuit Switcher Structure

The circuit switcher stand was a single leg design and required a similar steel base as used for the dead-end tower for stability. In addition, the steel support stand was too short for our application and needed to be raised a little over seven feet to maintain phase to ground and safety clearances for the conductor leads. With a little more help from our steel fabricator, we designed a seven foot high box beam extension with mounting plates top and bottom. The extension was bolted to the base, then the circuit switcher was mounted on top of the extension. The base was secured to the parking lot surface with epoxy type anchors.

Steel Box Structure

Assembly of the steel box structure commenced on Friday, June 20th. The structure could not be assembled in its final location due to space constraint of the site. The switchgear building was not due to arrive until the following day. The size and weight of the switchgear forced the crane to set up in the final location of the steel box structure. Therefore, to keep on schedule the box structure was assembled in an area directly adjacent to its final installation location. The plan was to set the switchgear, relocate the crane, pick up the assembled steel structure, and set it in place.

Assembly of the box structure was completed late Saturday afternoon and set in place early Saturday evening. The structure was secured to the concrete with epoxy type anchors.