DULUTH 34 kV UPGRADE

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Background:

In 2000, Minnesota Power (Frank Kornbaum) published a report that both defined a problem and offered a solution. The problem analysis study confirmed that a catastrophic loss of the largest 115 – 13.8 kV substation in Duluth (15th Avenue West Substation) would result in long duration customer outages. Much of the load is located in the downtown Duluth area and could not be transferred to another source if the entire 15th Avenue West Substation source was lost.

A first contingency plan was needed as a solution to handle this catastrophic event. Finding a solution included a risk and loss management evaluation. Both financial and political risks had to be considered. If this event occurred, many large and important customers could be left without power for an extended period.

Several options were evaluated. An upgrade to a 34 kV system (operating at a nominal value of 34.5 kV, referenced as 34 kV in this paper) was the favored solution. This upgrade would ultimately provide the first contingency plan for the complete loss of the 15th Avenue West Substation and offer improved reliability and voltage support for the rest of the distribution system during normal operation. The increased capacity would also provide for long-term load growth (estimated at forty plus years using current growth rates) within the city.

The 15th Avenue West Substation:

The 15th Avenue West Substation is one of the oldest substations in the system and is the heart of the downtown power system. Two 115 kV lines on a looped transmission system provide the source for the substation's three transformers. Typical loading of the substation is around 75 MVA with peaks approaching 90 MVA. Maximum capacity of the transformers is 106 MVA. The station is tied to the distribution system through sixteen 13.8 kV distribution feeders. The existing distribution feeders are not capable of supplying the energy needs of the downtown area without the 15th Avenue West Substation source intact. Under peak loading conditions, only nine of the sixteen feeders could be adequately fed from other substations at an acceptable voltage level. When distribution circuits are heavily loaded, customers may experience unacceptable voltage drop and capacitor switching transients.

A Plan Comes Together:

The Duluth 13.8 kV circuits are rated at 12 MVA. A 34 kV feeder utilizing the same size conductor is rated at 30 MVA. This significant increase in capacity can be realized while still maintaining distribution level voltages and class equipment. Keeping it at a sub-transmission level, the system avoids many installation costs, safety concerns, and difficulties typically faced at transmission levels. This voltage level is also more acceptable to the public.

In order to utilize 34 kV feeders, the project includes the placement of three 115 – 34 kV station transformers at three different locations. Additional load forecasting, system modeling, and planning shows enough value that a fourth location will likely be added to the system. These stations will be tied together with new 34 kV circuits. Some of the existing lines have already been converted to 34 kV in

preparation for the new system, but are currently only operated at 13.8 kV. The 34 kV source points and lines will facilitate the transfer of 30 MW of load from existing 115 – 13.8 kV stations to the 34 kV system.

The 34 kV will provide a backbone to accommodate more power to be brought downtown, but the actual distribution will still occur at 13.8 kV. The only customers that will be served directly from the 34 kV system will be two large medical facilities. All other customers will be served from pad-mounted step-down transformers located in areas with high concentrations of load. The step-down transformers provide a 13.8 kV source from the 34 kV system. These sources will tie to existing distribution circuits to use the infrastructure that is already in place.

The first 115 – 34 kV substation was placed in service in 2010. The second source substation is planned to be energized by October 1, 2011. The third source is scheduled to be put in service early in 2013. The attached oneline shows the anticipated layout around this time.

Increased Reliability:
By using this approach to solve the problem, there are opportunities to improve the reliability of the distribution system. Most customers in the Duluth area will see an increase in reliability when the 34 kV project is complete. Some of the existing feeders will be shorter and feed fewer customers. This will reduce that feeder's exposure to faults.

The backbone of the 34kV system will be protected and controlled by intelligent switching devices. Using automatic reconfiguration and segmentation of the feeder, the 34 kV system will be "self healing" for many fault conditions. When a fault occurs, intelligent switches will isolate the faulted portion and restore power without the need for human intervention. Communication systems back to the EMS will report the system changes so crews can be dispatched to repair the fault. By breaking the backbone into a number of smaller segments, less ground will have to be investigated to identify a problem.

Rather than building large substations we will install 5 MVA step-downs at retired 4 kV substation sites in downtown Duluth and at load centers along the 34 kV corridor. Using smaller step-down transformers means that fewer customers will be fed from each location which in turn reduces the exposure to faults in the 13.8 kV system.

Distribution engineering will continue to utilize new technologies to identify and correct reliability issues on individual feeders. One example of this is the Telemetric (Sensus) monitors that we have installed on select circuits. These devices send us an email whenever voltage levels go outside of prescribed boundaries and whenever there is a momentary or sustained outage. Another example are the new "smart" meters being installed. These meters can provide accurate metering information and interrupt histories to help identify problems that may be present on the distribution system.

Improved Power Quality:
With the step-down transformers located near load centers there will be fewer line losses and less voltage drop. With the reduced line losses and voltage drop, we won't need to install as many capacitor banks and regulators. This will mean customers should see fewer to no switching events.

Circuits that originate from the step-down transformers will be isolated from faults on other 13.8 kV feeders. As an example, one feeder on the present 13.8 kV system may originate on a bus section with five other feeders. If a fault occurs on any of the circuits, it can cause the voltage at the bus to dip. This voltage disturbance would be seen by the unfaulted feeders on the bus. By having more sources with fewer feeders sharing a common bus, the disturbance may only affect one other feeder.

Load Transfer Contingencies:

Breakers and other equipment at the 15th Ave West Substation are antiquated and will need to be replaced in the near future. There are three main sections of switchgear that house up to seven feeder breakers each. To do the replacement, individual bus sections need to be de energized and dealt with individually. There is currently not enough feeder and transformer capacity at 15th Ave West Substation and the adjacent distribution feeders to carry the load with one full section out of service. With the completion of the 34 kV system, a significant amount of load will be transferred off of the substation. With this load removed, the remaining load can be transferred as needed to neighboring feeders and each switchgear lineup can be removed from service without a scheduled outage. Once the load is transferred onto the 34 kV system and the switchgear upgrade is complete, there will be more options available for transferring load within the distribution system.

Schedule and Costs:

The estimated cost for the 34 kV system upgrade is $7.2 million. Two substations make up approximately 60% of the total cost. The six step-down sites and conversions at the medical facilities account for 25% of the cost. The remaining 15% covers the cost of line construction and conversion. Note that a large portion of the line construction was incrementally completed in prior years and is not included in these totals. Prior to 2010, two 34 kV high-capacity feeders were constructed but have only been operated at 13.8 kV.

2010

A major circuit was converted to 34.5 kV in downtown Duluth.
The first 115 – 34.5 kV substation was energized.
The first 34.5 – 13.8 kV pad-mounted step-down substation was energized.
Procured real estate for step-downs planned to be built in 2011.

2011

115 – 34 kV transformer is installed at second substation site.
Second and third 34.5 – 13.8 kV step-down sites planned for construction and completion.
Complete a major portion of the 34 kV line construction from source to step-downs.

2012

Build and energize the third 115 – 34 kV substation.
Construct a segment of 34.5 kV line between two tie points to complete the loop.
Install an intelligent 34.5 kV automated switching system.
Construct and energize two more 34.5 kV – 13.8 kV step-downs.

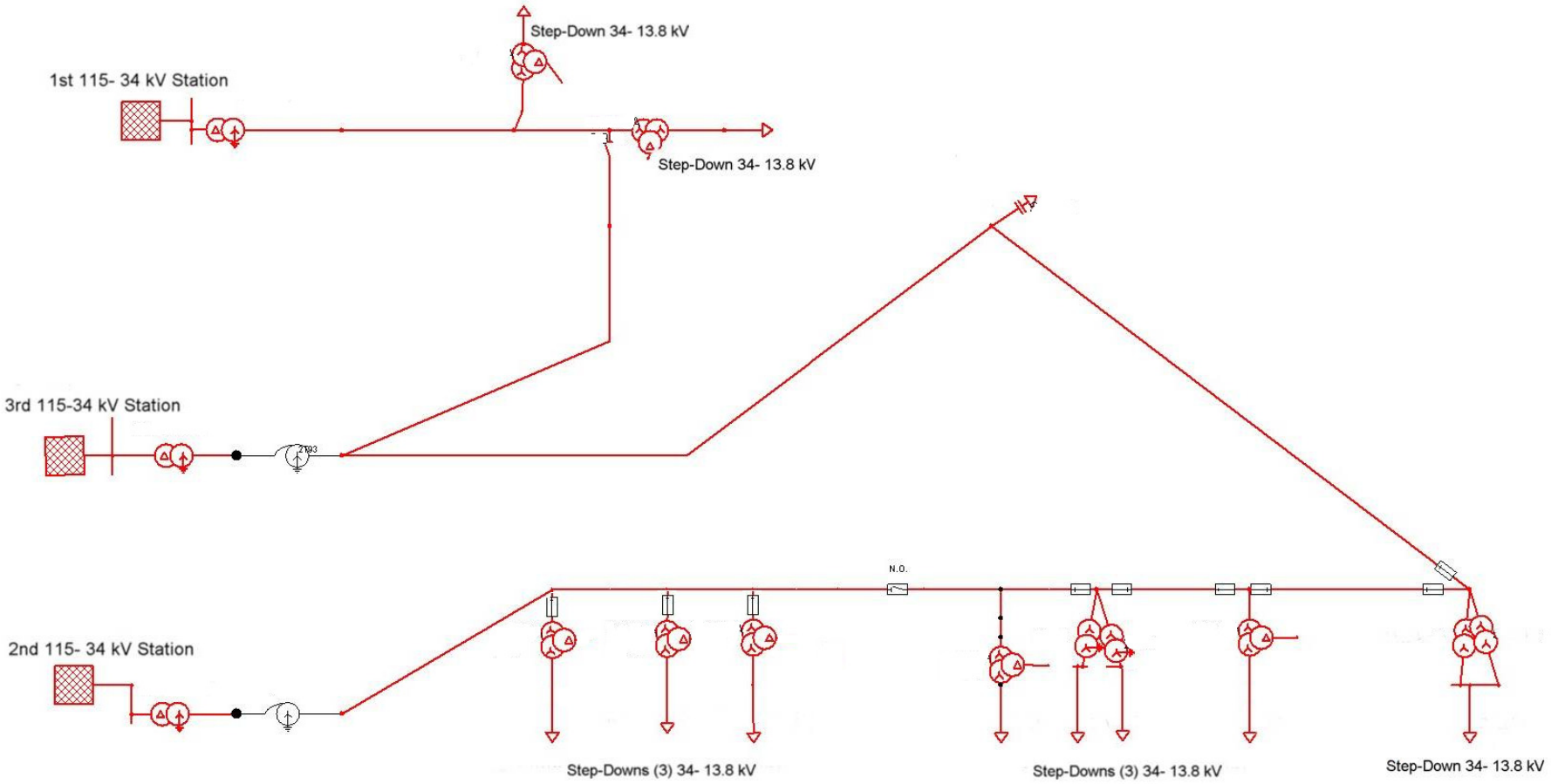
2013

Convert two medical facilities to be served from the 34.5 kV system.

Conclusion:

The 34 kV distribution system is necessary to alleviate loading problems in the existing 13.8 kV system. Power quality and reliability will be increased for customers who are served from the 34 kV system or affected feeders on the 13.8 kV system. With the 34 kV system in place, we will be able to upgrade the switchgear at the 15th Ave West Substation.

The 34 kV system will begin with three 115 – 34 kV substation sources and will relieve the existing 13.8 kV system of enough load to survive a catastrophic failure at the existing 15th Ave West Substation. Distribution engineering will continue studying load growth and evaluating alternate circuit configurations to determine if additional 115 – 34 kV sources need to be added after 2013.



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