Voltage Collapse Exposure for Decatur, IL

Uncertainties in Predicting Voltage Collapse

Although a voltage collapse is a dynamic process, planning engineers frequently use steady-state analyses (e.g., power flow models/tools) to identify areas that are exposed to this type of scenario. Planning engineers using models of the transmission system will typically take notice of any situation where the steady-state analysis shows transmission voltages would be below 95% of nominal. Additional review is performed to determine if the topology of the rest of the delivery system indicates there might be a problem. If a steady-state analysis shows transmission voltages below 85% of nominal, the assumption is that a voltage collapse is essentially certain for the conditions being examined. If a steady state analysis shows transmission voltages between 85% and 95% of nominal, additional review of the system in the area affected is needed. When the steady-state analysis shows voltages in this range, there is no bright line to identify if a voltage collapse will occur, since the exact characteristics of the load are not known. However, it is known that some motors connected to the distribution system will begin to stall when the distribution bus voltages fall below 90% of nominal.

Modeling the Decatur Area -- Conventional Modeling vs. More Detailed Modeling

In the periodic analyses of the Ameren system, the Decatur area was identified as possibly being vulnerable to a voltage collapse. A study performed in 2007-2008 confirmed that the area would be exposed to a voltage collapse. At that time, the load forecast for the Decatur area showed a total load of 660 MW in 2013. The analysis indicated that the area would be clearly exposed to a voltage collapse in 2013 or before. In response to this study, mitigation options were evaluated and the addition of a 345 kV line from Latham to Oreana was identified as the best solution. Due to lead time constraints, the target in-service date for the new Latham-Oreana line was set as 2014. Because the need for the line was so clear-cut at this time, there was no reason to consider more in-depth modeling of the area.

Since the time of the study, the area has experienced lower loads and the forecast of load was revised to 600 MW in 2013, increasing to 620 MW in 2016. In addition, a large industrial customer has indicated an interest in increasing its load by 30 to 100 MW.

Generally, power flow models used to evaluate the transmission system do not explicitly represent the details of the distribution system. Typically, the model explicitly shows only the transformers at distribution substations connected to the transmission system, with all of the downstream distribution system shown simply as a net load. Capacitors connected to the low-side bus of the distribution substation may or may not be netted with the load. The power flow model used in the analysis to support the direct testimony offered as AmerenIP Exhibit 1.0 in testimony related to the Latham-Oreana project used a net load representation at the low-side load buses for all substations connected to the transmission system. The models did include the

34 kV capacitor banks explicitly modeled at those busses that have 34 kV capacitor banks. However, the entirety of the rest of the distribution system was represented simply as lumped net load.

In responses to data requests related to Ameren's Latham-Oreana project, Ameren commented on various load levels and corresponding voltages *on the segments of the system included in the model*. Using 85% as a threshold for indication of a voltage collapse, the conclusion reached was that the Decatur area may not be exposed to voltage collapse in 2016. This was based on the standard power flow model and updated load forecasts that show lower future load levels. *(It should be noted that 85% is the level at which a voltage collapse is essentially assured. Situations which show 86% - 89% voltage in a steady-state analysis carry significant risk for voltage collapse.)*

The Transmission Planning staff at Ameren reviewed the model used in the initial evaluation of the Decatur area and determined that some assumptions made in the development of the model resulted in under-stating the exposure to voltage collapse. It was identified that the model could be improved by showing more detailed information for the underlying distribution system. Although a significant amount of detail could be added, it was decided that one key improvement would be to explicitly model the capacitors on the underlying distribution system instead of showing a net reactive load.

Results with More Detailed Power Flow Model

To include the effects of distribution capacitors, a power flow model was developed considering a 620 MW load level in the Decatur area expected by 2016 without the addition of new large customer loads (the same model that was used to develop the response to DR ENG 4.06 d). The distribution capacitors previously netted against reactive power load were modeled as a discrete item at all relevant distribution buses in the model.

A side-by side comparison of the bus voltages in the Decatur area for the double-circuit outage of the Clinton-Latham 345 kV line 4571 and the Clinton-Goose Creek 345 kV line 4545 shows that the case with the distribution shunt compensation capacitors modeled explicitly has lower voltages compared to the conventional net load model. (Bus voltages below 85% of nominal are highlighted in red; bus voltages below 90% but above 85% are highlighted in yellow.)

Decatur Area Double-Circuit Outage of Clinton-Latham line 4571 and Clinton-Goose Creek line 4545 Load Tap-Changers Locked				
Bus Number	Bus name	Bus voltages with conventional net load model	Bus voltages with shunt compensation capacitors modeled	Delta Voltage
84400	East Main 34 kV	0.9197	0.8943	-0.0254
84401	North Decatur 34 kV	0.9209	0.8943	-0.0266
84402	North Decatur 34 kV	0.9181	0.8923	-0.0258
84403	N 27th Firestone 34 kV	0.9193	0.8906	-0.0287
84404	N 27th Firestone 34 kV	0.9186	0.8926	-0.0260
84408	North Decatur 69 kV	0.9139	0.8777	-0.0362
84415	South Clinton 34 kV	0.9631	0.9382	-0.0249
84548	ADM North 34 kV	0.8945	0.8735	-0.0210
84549	ADM North 34 kV	0.9197	0.8932	-0.0265
84553	Cnty Hiway 20 34 kV	0.9275	0.8988	-0.0287
84554	ADM East 34 kV	0.8929	0.8715	-0.0214
84556	Northgate #1 12 kV	0.9030	0.8677	-0.0353
84567	Northgate #2 12 kV	0.8727	0.8160	-0.0567
84568	Route 51 #2 12 kV	0.9019	0.8767	-0.0252
84569	Route 121 #1 12 kV	0.8702	0.8197	-0.0505
84570	Clinton Rte 54 12 kV	0.9165	0.8898	-0.0267
84571	Route 51 #1 12 kV	0.8981	0.8712	-0.0269
84572	Clinton Rte 54 12 kV	0.9464	0.9304	-0.0160
84614	Route 121 #2 12 kV	0.9104	0.8987	-0.0117
348842	S Clinton Tap 138 kV	0.9116	0.9064	-0.0052
348845	Clinton Tap 138 kV	0.9178	0.9064	-0.0114
348853	ADM North 138 kV	0.8810	0.8623	-0.0184
348862	N Decatur W 138 kV	0.9041	0.8871	-0.0170
348863	N Decatur E 138 kV	0.8980	0.8807	-0.0173
348864	N 27th St 138 kV	0.8924	0.8743	-0.0181
348865	Decatur Jct 138 kV	0.8993	0.8816	-0.0177
348866	E Main St 138 kV	0.9013	0.8816	-0.0197
348867	Route 51 138 kV	0.9003	0.8828	-0.0175
348868	Route 51 Tap 138 kV	0.9013	0.8841	-0.0172
348869	Moweaqua Tap 138 kV	0.9387	0.9280	-0.0107
348870	Caterpillar 138 kV	0.8847	0.8662	-0.0185
348871	Faries Parkway 138 kV	0.8804	0.8617	-0.0187
348872	Mt. Zion 121 138 kV	0.8882	0.8696	-0.0186
348873	Mt. Zion PPG 138 kV	0.8922	0.8741	-0.0181
348876	Clinton Rte 54 138 kV	0.9133	0.9009	-0.0124
348877	Cnty Hiway 20 138 kV	0.8983	0.8819	-0.0164

Max		0.9631	0.9382	-0.0567
Min		0.8702	0.8160	-0.0052
Avg		0.9064	0.8838	-0.0226

In general, modeling distribution shunt compensation capacitors provides an average difference of about 2.3% in the Decatur area compared to net load modeling. The additional detail shows a larger impact on distribution bus voltages than the transmission bus voltages because of the increased voltage drop through the bulk and distribution substation transformers. The heavily loaded 138-12 kV substations at Northgate #1 and Mt. Zion Route 121 #1 have voltage differences exceeding 5% compared to net load modeling.

With 12 kV bus voltages less than 82% at these two stations, and less than 82% downstream on the distribution feeders, it is Ameren's opinion that many motors connected to these stations would stall. The real power demand of the stalled motors would increase significantly, and the reactive power demand of the stalled motors would increase drastically, further decreasing the area voltages and causing more motors to stall, resulting in a rapid deterioration of the voltages and ultimate collapse of the Decatur area.

It should also be noted that an even more detailed model (including distribution feeders, etc.) would probably show even worse voltages. Also, this steady-state analysis does not consider the added impact of load characteristic change due to a transmission fault. Although the industry has not yet developed a Good Utility Practice which would provide a framework for including this aspect, the phenomenon is present and would make the situation worse than indicated by the steady-state analysis.

Conclusion

Power flow analysis of the Decatur area indicates the area will be exposed to voltage collapse by 2016 (or before). The voltage collapse would result in the loss of service to most if not all of the load (over 600 MW) in the Decatur area. A loss of this magnitude far exceeds the 300 MW limit in Ameren's Transmission Planning Criteria for the amount of load dropped by the natural response of the system. In order to avoid exposure to this outage and to comply with Ameren's Transmission Planning Criteria, the Latham-Oreana 345 kV project should be completed by 2015.