Mayflower EHV – Tornado Restoration

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Entergy

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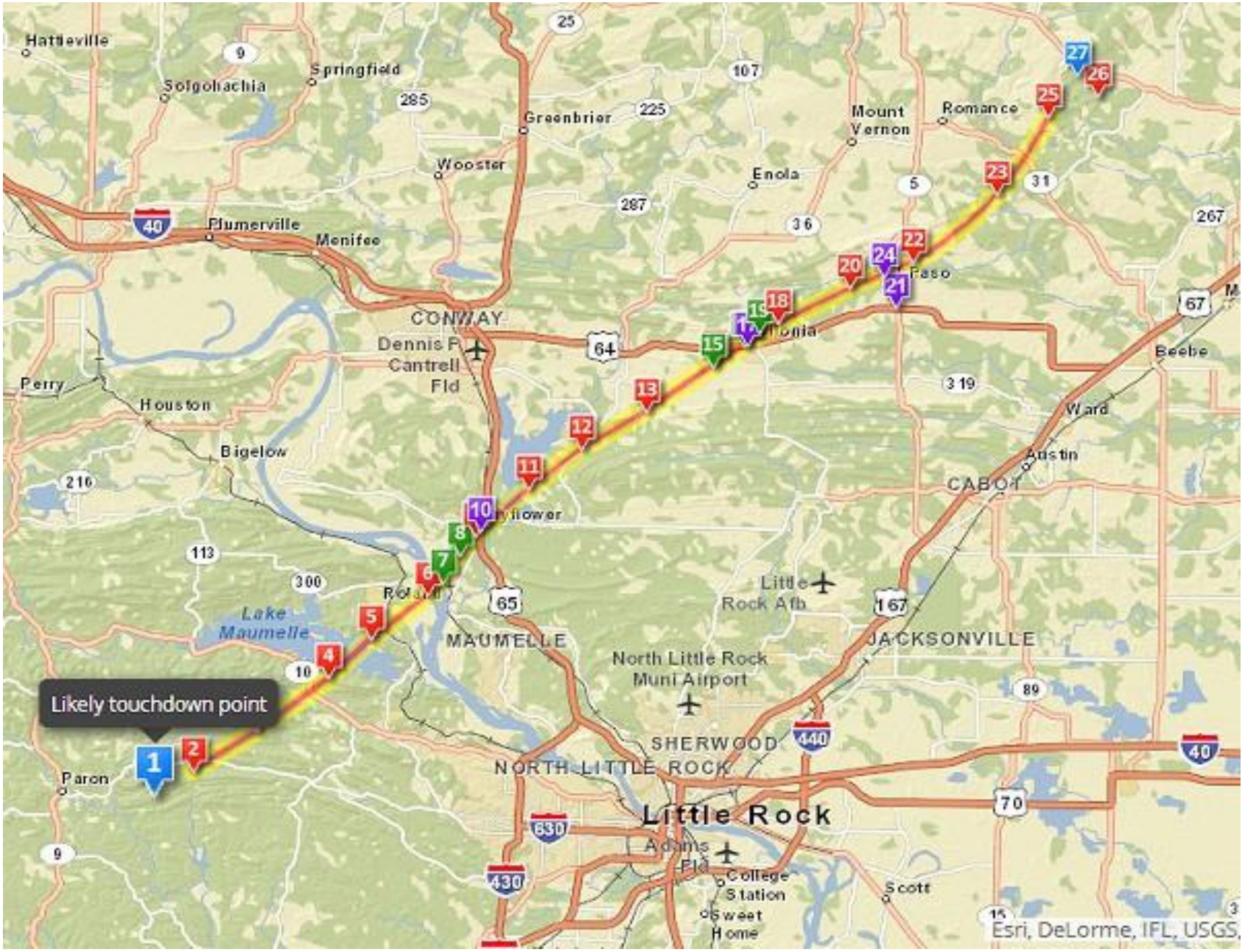
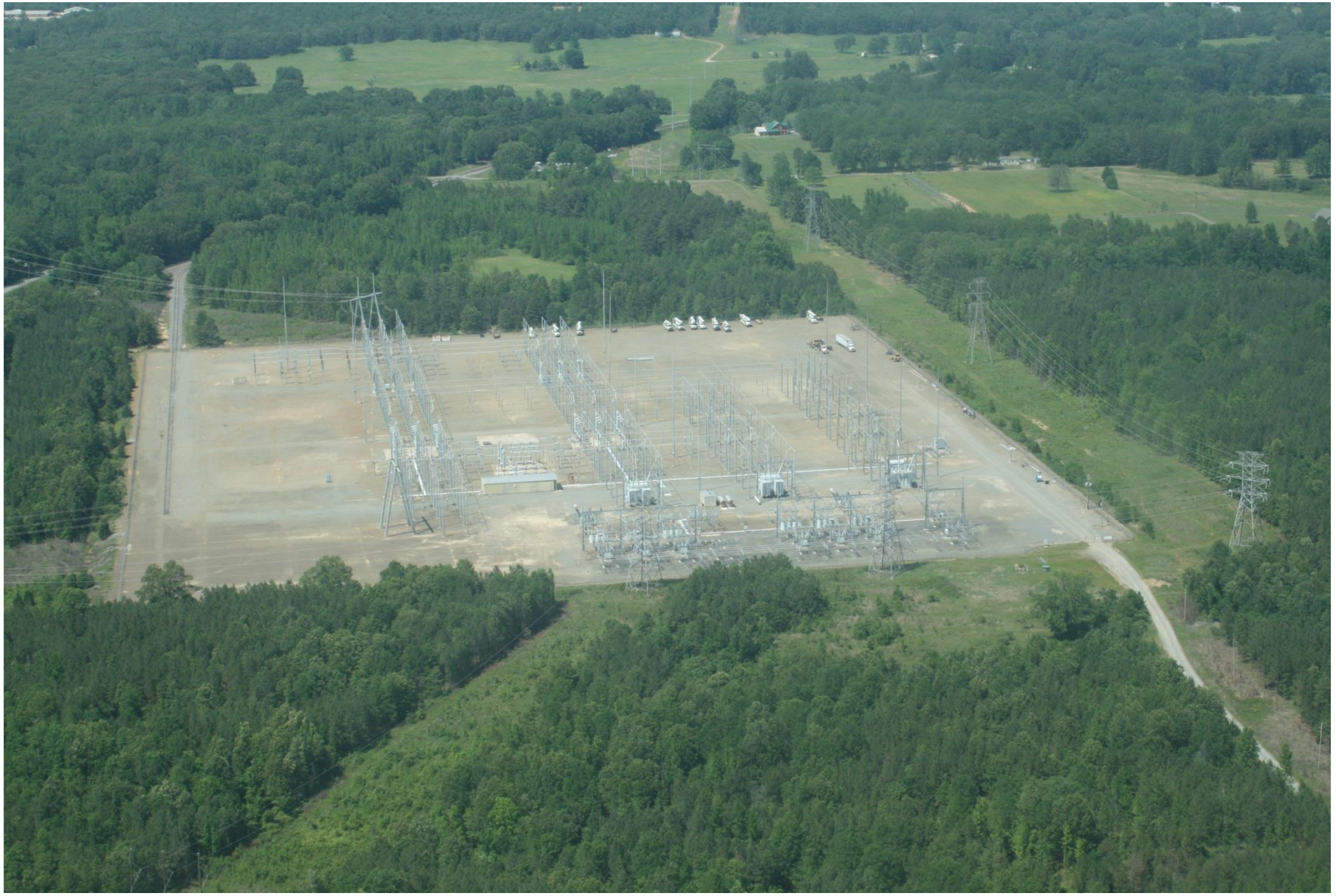
Background

On April 27, 2014, five tornadoes ripped through Arkansas, packing winds up to 200 miles per hour. Entergy's Mayflower EHV 500kV substation sustained a direct hit from one of the tornadoes registering as an EF4 on the Enhanced Fujita Scale. Roughly 70% of the substation was destroyed. Mayflower is a critical substation within the Arkansas 500KV system, providing power into the 115KV grid via three auto-transformers.

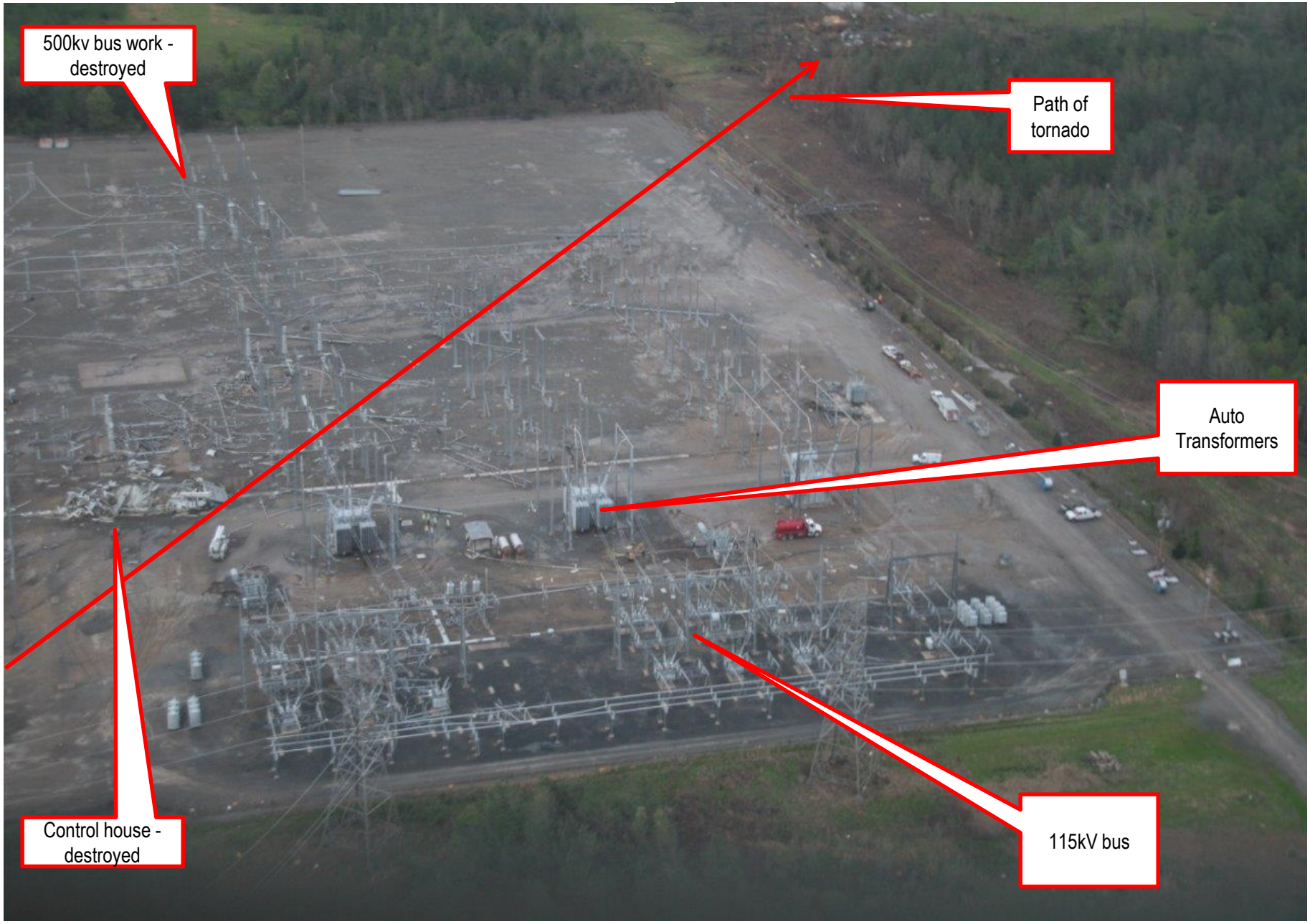

Likely touchdown point
Hattieville
Springfield
Solgohachia
Greenbrier
Mount Vernon
Romance
Wooster
Enola
Plumerville
Menifee
CONWAY
Dennis P Cantrell Fld
Perry
Houston
Bigelow
Beebe
Ward
Austin
CABOT
Lake Maumelle
MAUMELLE
Little Rock Afb
JACKSONVILLE
North Little Rock Muni Airport
SHERWOOD
NORTH LITTLE ROCK
Little Rock
Paron
Adams Fld
College Station
Sweet Home
Scott
Esri, DeLorme, IFL, USGS,

Mayflower 500/115kv EHV Substation - before

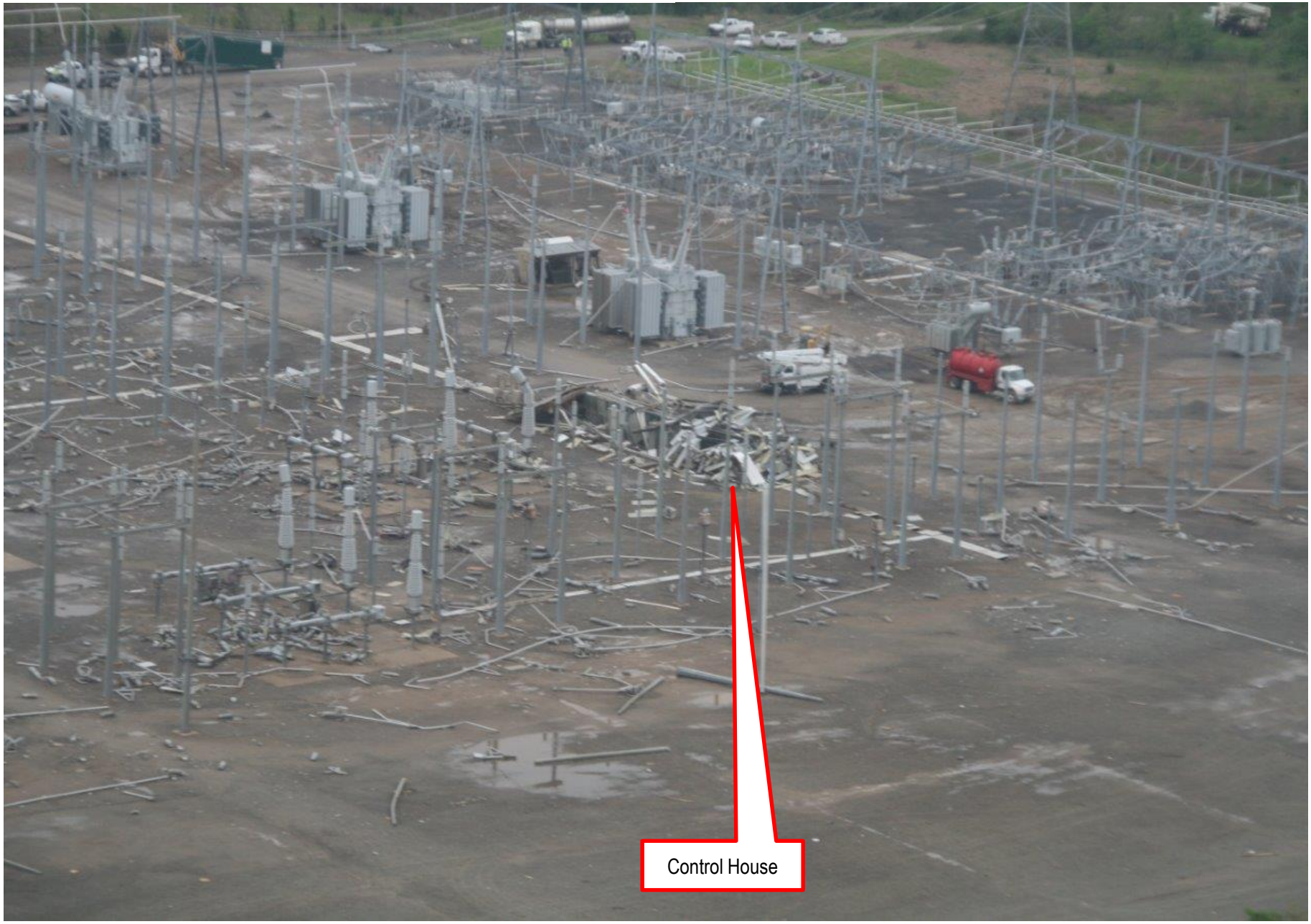


Mayflower 500/115kv EHV Substation - before

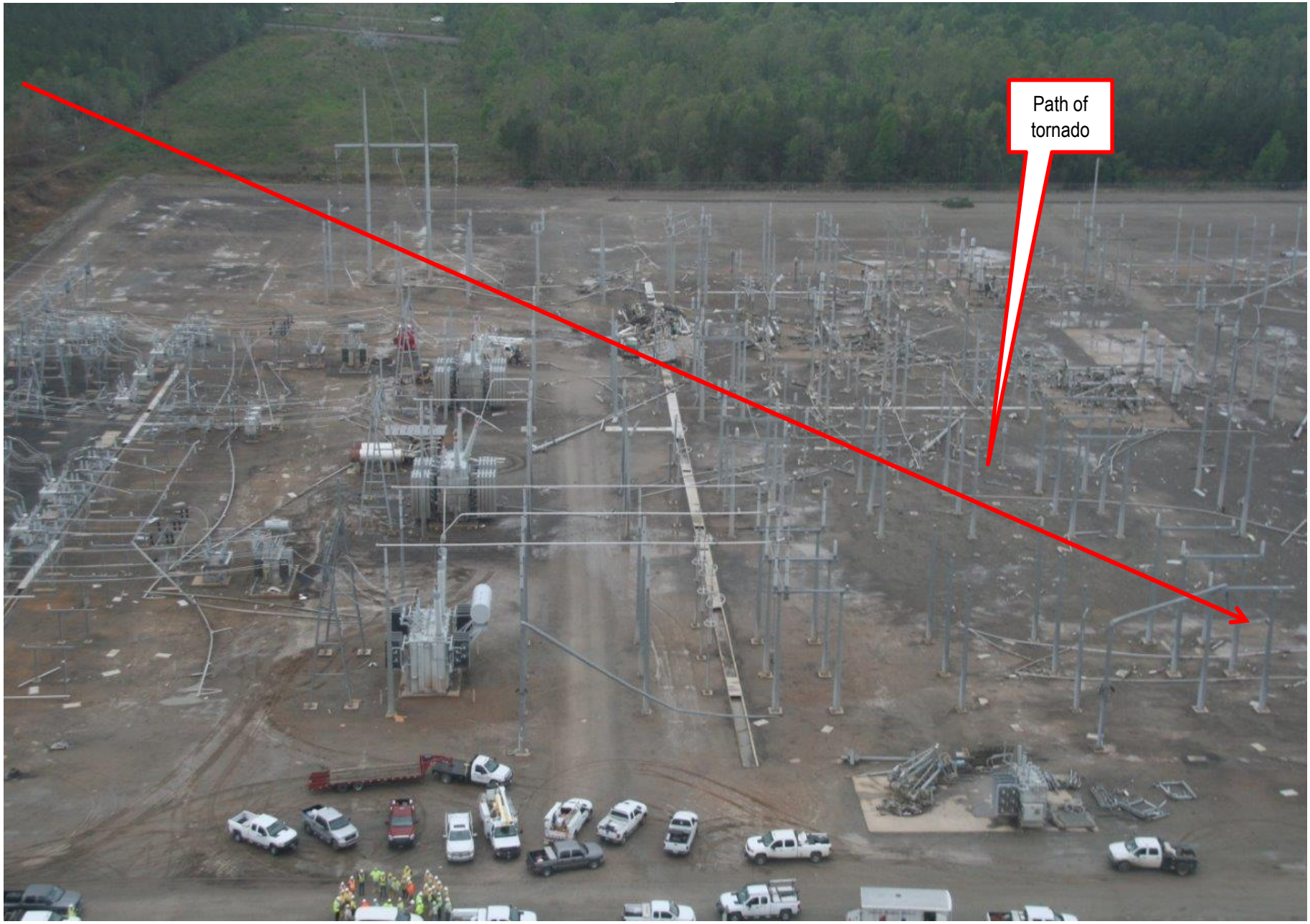
Mayflower 500/115kv EHV Substation - after



Mayflower 500/115kv EHV Substation - after



Mayflower 500/115kv EHV Substation - after



Mayflower 500/115kv EHV Substation - after

Mayflower 500/115kv EHV Substation - after

The Approach:

- A unique two phased approach to restoring the substation was used.

- The first phase was a temporary solution that returned the substation to service by June 3rd, 2014; exactly 37 days after being destroyed.

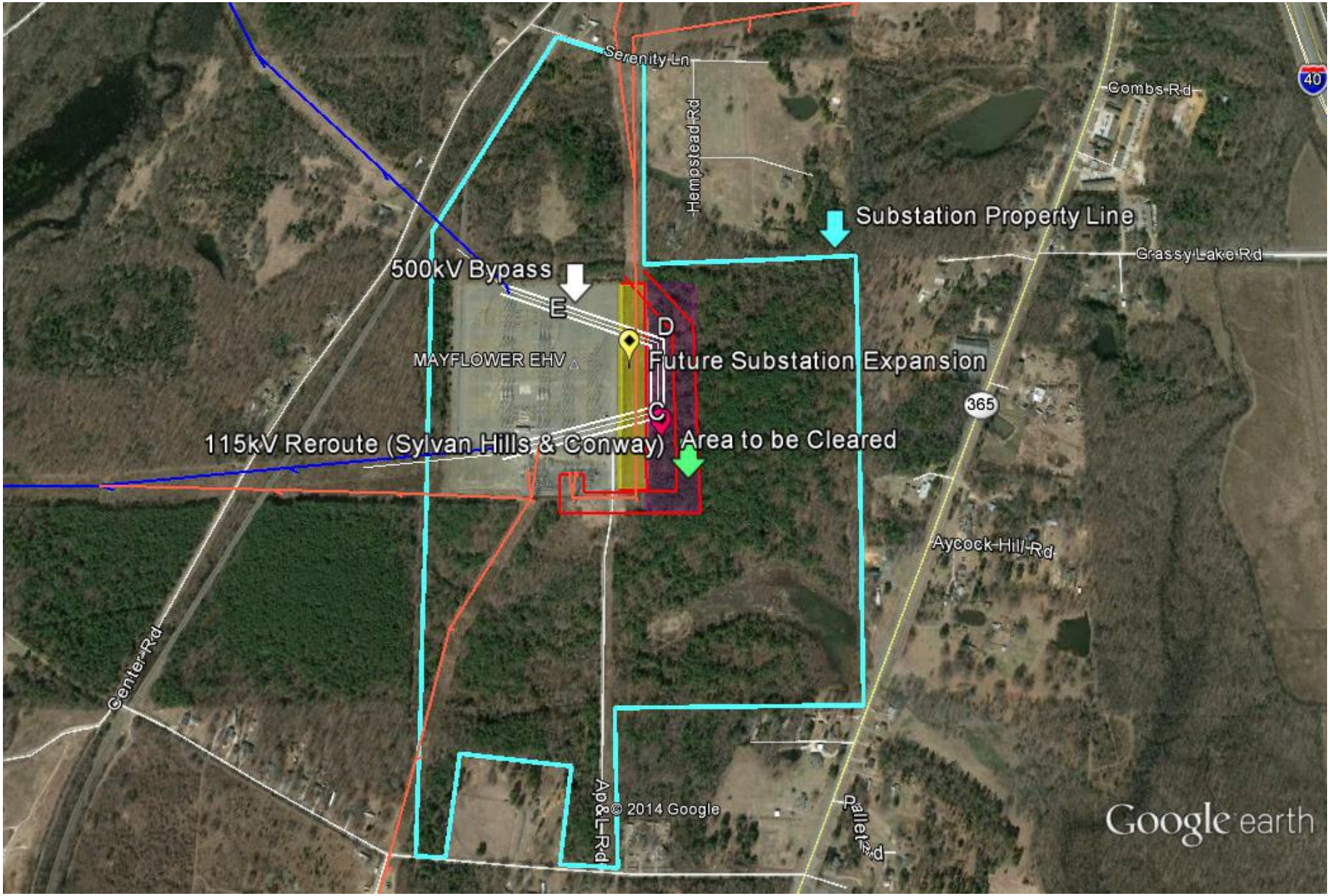
- The second phase was the permanent solution that converted the existing 500KV ring bus to a breaker and a half arrangement.

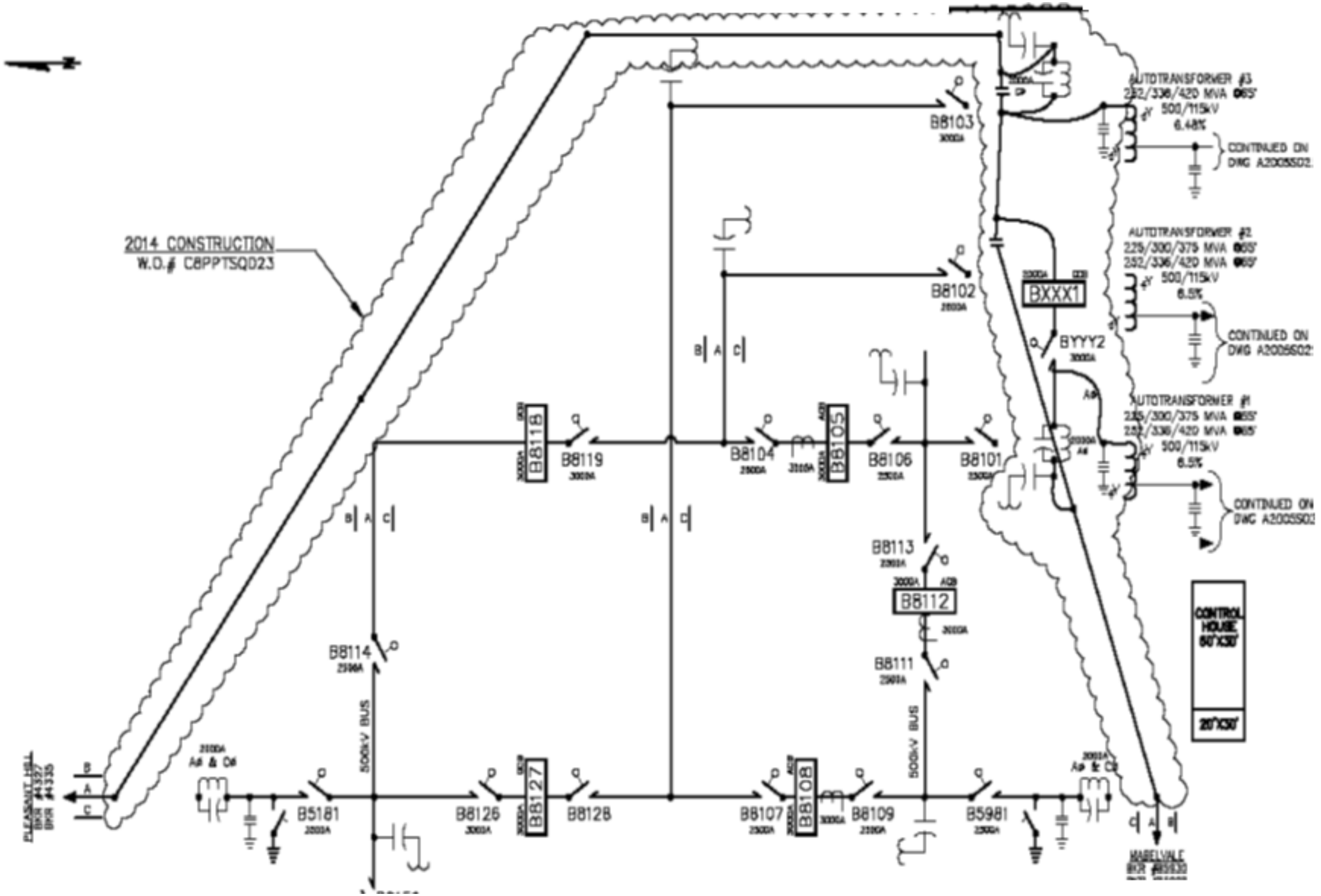
Temporary Solution

- The challenge was to develop a temporary solution with the limited amount of physical and relay material available. The goal was to restore at least two auto-transformers and reconnect them to the two 500 KV transmission lines leaving the substation.
- Material needed to reconstruct the 500KV bus was not available in the timeframe needed.
- String bus was used to create a temporary bypass.
  - Triple bundle transmission line would connect to the existing dead-end structure and run across the yard, passing in front of the autotransformers and eventually connecting to the dead-end structure for the other transmission line. Steel and wooden poles would support this string bus high above the substation to allow for future bus work to be constructed at a normal EHV height without having to take the by-pass out of service.
- In order to provide high side separation between the two auto-transformers a breaker and motor operated switch were placed between them.

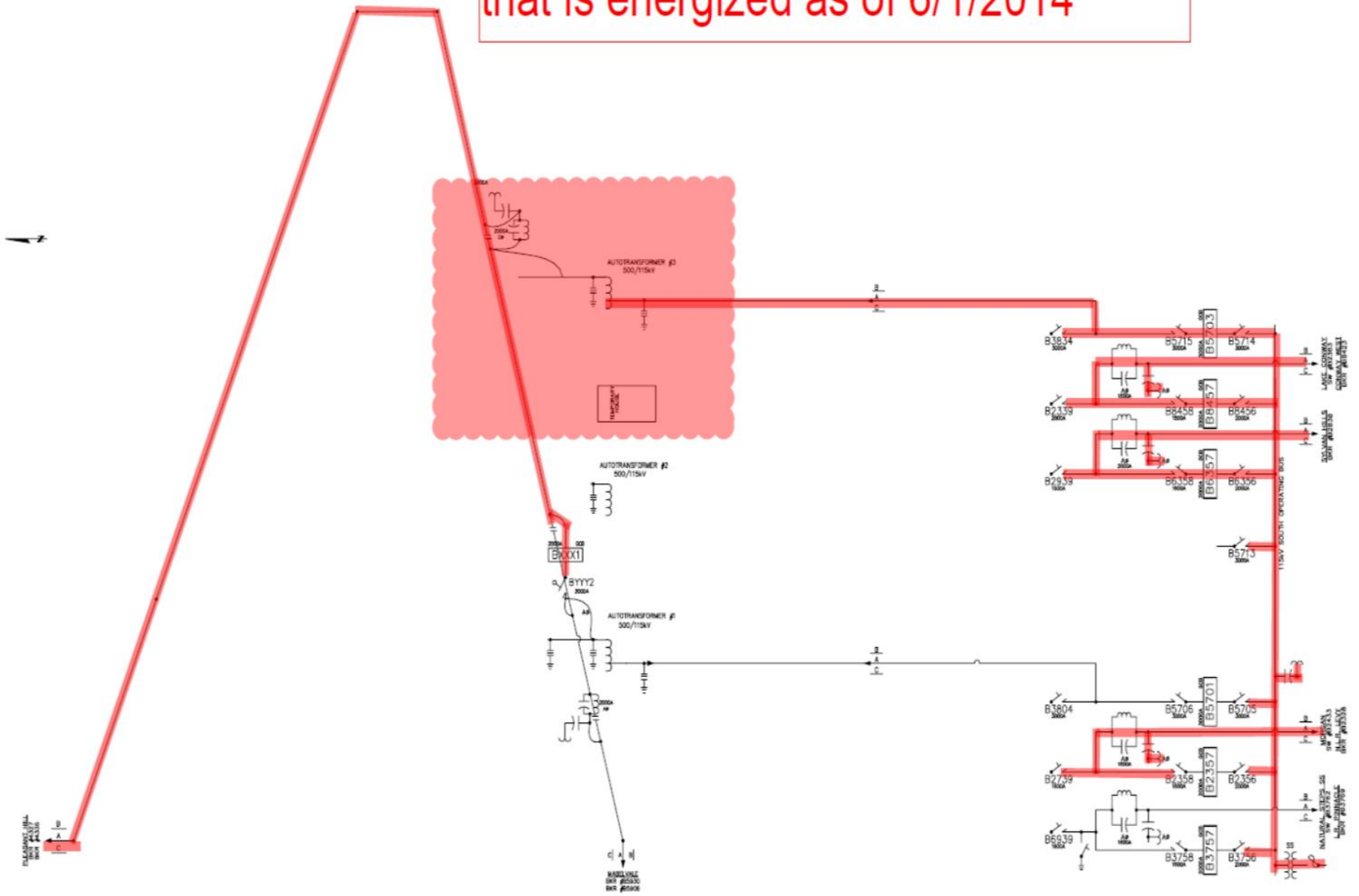
Temporary Strung Bus Material List

- 40 – insulators
- 12 – steel poles and foundations
- 12 – grounding poles
- 2,800 feet – guy wire
- 40,000 pounds of 954/ACSR conductor
- 8,000 feet – shieldwire


Serenity Ln
Hempstead Rd
Combs Rd
40
Substation Property Line
Grassy Lake Rd
500kV Bypass
E
D
MAYFLOWER EHV
Future Substation Expansion
365
C
115kV Reroute (Sylvan Hills & Conway)
Area to be Cleared
Aycock Hill Rd
Center Rd
Ap&L Rd
© 2014 Google
Google earth


2014 CONSTRUCTION
W.O.# C8PPTSQD23
AUTOTRANSFORMER #3
252/336/420 MVA 65°
500/115kV
6.48%
CONTINUED ON
DWG A2005502
AUTOTRANSFORMER #2
225/300/375 MVA 65°
252/336/420 MVA 65°
500/115kV
6.5%
CONTINUED ON
DWG A2005502
AUTOTRANSFORMER #1
225/300/375 MVA 65°
252/336/420 MVA 65°
500/115kV
6.5%
CONTINUED ON
DWG A2005502
B8103
B8102
BXXX1
BYYY2
B8116
B8119
B8104
B8105
B8106
B8101
B8113
B8112
B8114
B8111
B5181
B8126
B8127
B8128
B8107
B8108
B8109
B5981
500kV BUS
500kV BUS
CONTROL
HOUSE
60'X30'
20'X30'
PLEASANT HILL
BKR #4337
BKR #4335
MABELVALE
BKR #8930

Red represents portion of the station that is energized as of 6/1/2014



Bypass Installed

Bypass Installed

Bypass Installed

Bypass Installed

Project Challenges

- Safety
- Environmental
- Procurement
- Protection and control issues
- Operational constraints

Safety & Environmental

- Batteries within the control house continued to leak acid into the cable trough system
  - Quarantined to prevent further exposure and contamination
- A bucket truck laid on top of the control house
  - After being removed the structure was deemed safe enough to enter
- Two of the three 500/115KV auto transformers, holding roughly 24,500 gallons of oil each, were damaged and leaking oil.
- There were numerous twisted structures in the substation and transmission line right of ways.
  - These structures could not simply be unbolted and taken apart; with the twisting of the steel, every structure had to be approached with a safety conscious mindset.
- There was at least one safety coordinator present onsite everyday during the temporary restoration.
  - Each morning began with a group safety moment before work started followed by individual group tailboards.

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Procurement

- **Major components damaged: by the numbers**
  - 64 Transmission line structures spanning 90 miles on 8 line segments
  - 27,500 feet of 500kV/115kV bus work
  - 18 - 115kV switches
  - 18 - 500kV switches
  - 9 - 115kV breakers
  - 8 - 500kV breakers
  - 3-6 inches of SB2 gravel stripped from the substation floor
  - 1 - control house

Procurement continued…

- Relay Material for Temporary Arrangement
  - 6 Transmission Line Panels
  - 2 Transformer Differential Panels
  - 1 Bus Differential Panels
  - 1 Dual Breaker Control Panel
  - 1 SCADA RTU
  - 1 HV Circuit Breaker
  - 1 Battery Trailer
  - 1 Battery Charger
  - Additional minor material was needed.

Procurement continued…

- Relay Material for Permanent Arrangement
  - New control house
  - 2 - Battery sets
  - 60 - Relay panels
  - 4 – 500kV Line traps
  - 4 – 115kV Line traps
  - 16 – 500kV CCVTs
  - 13 – 115kV CCVTs
  - 800,620 feet of control cable
  - 15 – 500kV switches
  - 8 – 500kV breakers
  - 2 – RTUs

Mayflower 500/115kv EHV Substation - after

Autotransformers: list of repairs

- Radiators
- Bushings
- Controls/pumps/gauges
- Seals and gaskets
- Arrestors
- Manifold
- Oil processing in all three transformers

Protection & Control Challenges

- With limited material
  - single phase carrier communications between Mayflower and the two remote 500KV substations.
  - The transformer differential panels used didn't meet our typical level of auto-transformer protection standards; however they provided the minimal amount of protection needed.
  - Without a high side interrupting device to disconnect the transformers from each transmission line, the protection scheme was setup to trip the 500KV tie breaker and key a transfer trip to either remote end in the event of a transformer differential operation.

Protection & Control Challenges

- Load flow studies indicated thermal overloads for first contingency loss of one auto transformer.
  - To mitigate this concern, a unique tripping scheme was put in place to companion trip the North Little Rock Levy line's breaker any time one of the autos tripped to prevent the remaining auto transformer from overloading.
- With the single 500KV breaker arrangement there was concern about the possibility of the 115KV back feeding the 500KV. Should the 500KV breaker that tied the two 500KV lines together trip without either low side breaker tripping, the concern was that power would flow from one 500KV line through the 115KV bus and back onto the other 500KV line.
  - Reverse power elements are not typically implemented within our breaker control relays, but to insure that the previously mentioned situation wouldn't happen the 32 element in the relays were used to trip under a set MW flow in the reverse direction.

Temporary control house

Control House and Batteries

- Where to place the protection panels?
- The core team was fortunate to find a vendor that had a control house that could be delivered in time.
  - The available control house had only enough room to accommodate the required panels, which meant no space remained for a battery set.
- The team decided to use a temporary battery trailer from the maintenance department. The battery trailer was positioned adjacent to the temporary control house with cables connecting it to the disconnect switch in the house.

Permanent Solution

- Constructing the permanent solution wasn't as difficult as someone may expect; the bypass was arranged so that only a limited amount of work would be needed near energized conductors.
  - A breaker and a half arrangement was constructed with the auto transformers not sharing a common breaker.
- The only challenge here was switching from the temporary solution to the permanent arrangement, from a relay protection perspective.
  - Taking a complete station outage wasn't an option.

Switching to the permanent arrangement

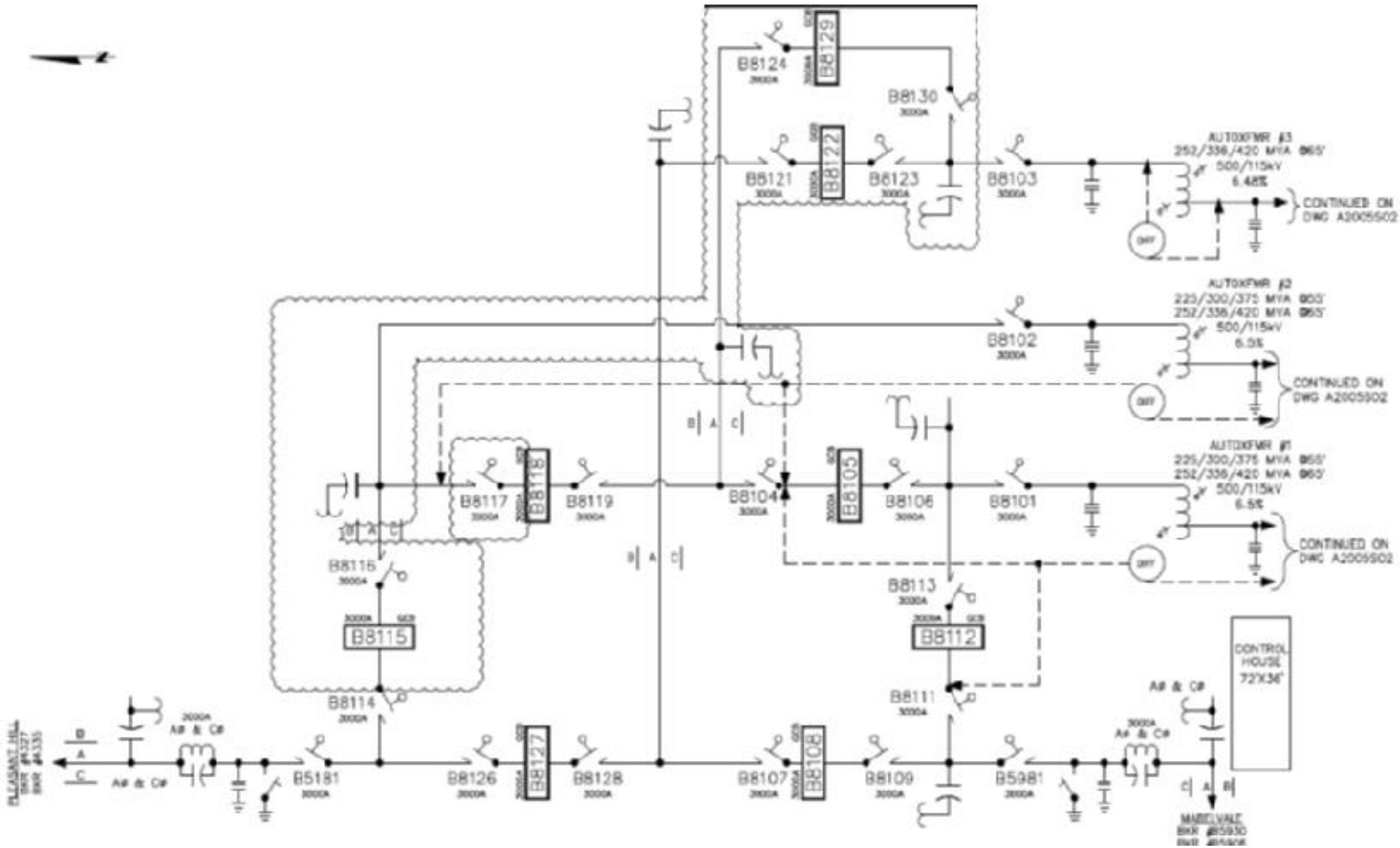
- Auto transformer 2 was connected to the new bus work since it was never energized with the temporary portion.
  - This along with the 115KV north bus was tested and commissioned prior to the cut over.
  - Next an outage on one of the 500KV lines along with auto transformer 3, was taken so they could be transferred to the permanent solution.
  - These two transformers along with the one 500KV line were energized, providing power to the north 115KV bus.
  - The 115KV lines were then transferred one at a time to the north bus.
    - The permanent solution was designed so that the 115KV breakers between the lines and the north bus would have line/breaker control so that this step would be possible.
  - The last auto transformer and second 500KV line were then taken out of service and transferred over to the new relay protection and permanent solution.
  - The last step was to test and commission the breaker control and bus differential for the south bus and breakers tied to it.

Bypass Removed

Bypass Removed

Bypass Removed

Permanent Solution Energized


B8129
B8124
B8130
B8122
B8121
B8123
B8103
AUTOXFMR #3
252/336/420 MVA @65°
500/115kV
6.48%
CONTINUED ON
DWG A2005502
B8102
AUTOXFMR #2
223/300/375 MVA @55°
252/336/420 MVA @65°
500/115kV
6.5%
CONTINUED ON
DWG A2005502
B8118
B8117
B8119
B8104
B8105
B8106
B8101
AUTOXFMR #1
225/300/375 MVA @65°
252/336/420 MVA @65°
500/115kV
6.5%
CONTINUED ON
DWG A2005502
B8116
B8115
B8113
B8112
B8114
B8111
CONTROL
HOUSE
72'X36'
A# & C#
B5181
B8126
B8127
B8128
B8107
B8108
B8109
B5981
MARCELVALE

Conclusion

- What worked well
  - The strung bus high above the substation played a significant role in the permanent solution not impeding the temporary arrangement.
  - Relied on familiar consultants from engineering to construction/demolition because of the fast pace.
- Lessons learned
  - Very fortunate to be able to borrow relay material from on going projects, if this wouldn't have been available it would have significantly impacted our schedule.
  - We now have a control house with panel for storm restorations in the future.
  - For the temporary design, the core team should have engaged planning during the brainstorming stage for contingencies that might be in place.

Questions?