2022 Fault and Disturbance Analysis Conference

GTC Fault Trace Tool Case Studies

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Abstract

Georgia Transmission Corporation (GTC) utilizes a Fault Trace Tool to provide near real-time visualization of fault distance(s) on a map of the transmission line, overlaid with lightning strikes in the area, and includes the status of any fault indicators on the faulted transmission line. This paper presents use case scenarios where the Fault Trace Tool proved to be extremely helpful in visualizing where faults were located on the transmission line. These scenarios include multi-tap fault locations, double ended fault analysis, fault indicator successes, and faults with lightning.

1. OVERVIEW

Georgia Transmission Corporation (GTC) is an electric membership cooperative owned by the 38 Georgia EMCs it serves. GTC is a member of the Integrated Transmission System in Georgia, along with Georgia Power, Dalton Utilities, and MEAG Power.

In 2014 GTC began researching a Fault Trace Tool (FTT), and tried working with several different vendors in search of a solution to display an X on the transmission line at a measured fault distance. During this search, GTC discovered that the cost to create a custom software with existing vendors was not only cost prohibitive, but left GTC footing the bill only to have a vendor own the final product. In 2020, GTC connected with the current vendor and found a solution for a Fault Trace Tool that had acceptable costs and allowed GTC to have the copyright of the product.

In the fall of 2020, the Fault Trace Tool was rolled out at GTC. The phase 1 rollout included using fault distance data from GTC Digital Fault Recorders (DFRs) to provide an automatic fault location map within the GTC fault email, a FTT webpage to display a map using manually input fault distances, a manual entry double ended analysis displaying fault distances from both ends of the transmission line, and the ability to click on a structure and measure back to a substation.

Spring 2021 included additions to the FTT, such as: an automatically generated lightning overlay on the fault map, the ability to run a lightning study from the FTT webpage, inclusion of Georgia Power DFRs in the automatic fault email maps, and display of fault indicator status at the time of a fault on the map.

Currently, GTC is in the final stages of rolling out an EMC Lightning Viewer, which utilizes the lightning layer capabilities and makes them freely available to our EMC Members to overlay on their GIS maps through our Member Portal. Likewise, GTC has plans in 2022 to make the FTT open source, so that other utilities can use the tool with their GIS system.

As with any project, there were several hurdles we had to work through to make the tool work appropriately. For instance, when relying on DFRs to measure the correct fault distance down the transmission line, the individual line lengths and line impedances need to be kept up-to-date

for the most accurate analysis. Additionally, there was a yearlong effort to clean up the background GIS information – ensuring that transmission lines were connected to substation frames, that each segment of the transmission line was connected to each other, verifying the accuracy of line IDs and normally open switch designations – so it is vital to the success of the FTT that the GIS information be kept up to date moving forward.

2. FAULT TRACE TOOL CAPABILITIES

GTC decided to incorporate a map from the Fault Trace Tool into our existing PQ Dashboard DFR fault emails and also have a new FTT website created. These two outlets enable the creation of an email with a map of DFR fault distance locations as well as the ability to manually plug in relay fault distance into a webpage to produce a map.

The example below shows what the original PQ Dashboard fault email looked like.

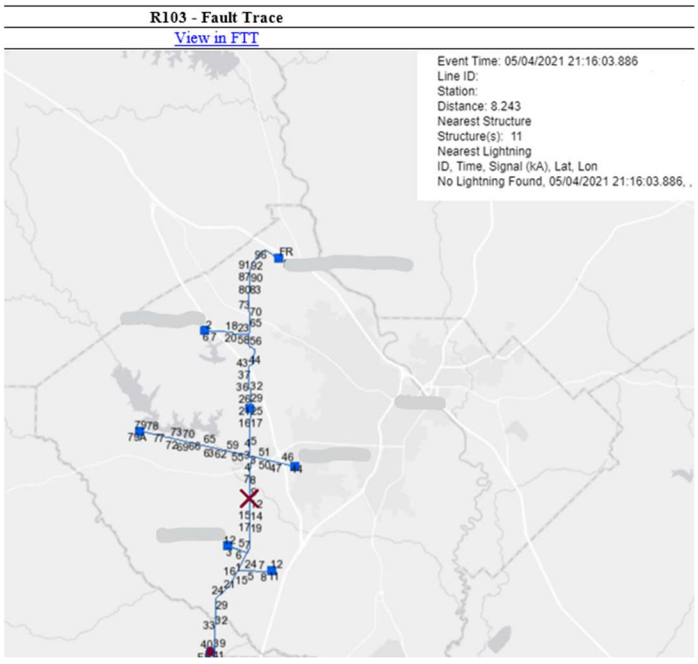
Fault 1 - 2021-05-04 21:16:03.8862496
DFRs: R103 at triggered at 21:16:03.7335413 (click for waveform)

Files: 210504,211603833,-5t,

Line: 115kV LINE (19.57 miles)

	- R103
Fault Type:	AN
Inception Time:	21:16:03.8862496
Fault Duration:	133.750 msec (8.03 cycles)
Fault Current:	1331.6 Amps (RMS)
Prefault Current:	235.3 Amps (RMS)
Postfault Current:	18.8 Amps (RMS)
Distance Method:	ModifiedTakagi
Single-ended Distance:	8.243 miles
Is Breaker Restrike?:	N/A
Short file name:	R103F4640.dat
openXDA Event ID:	1534220

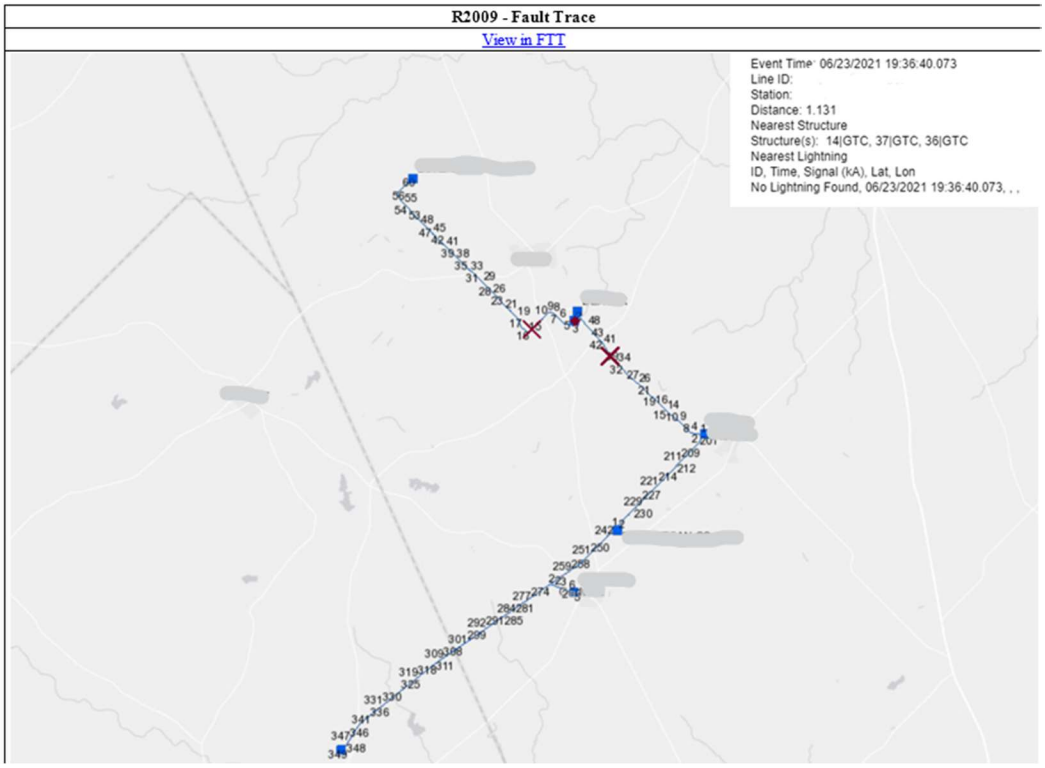
The FTT project added an additional map below the fault email information above, and now includes an X on the transmission line, as seen below.



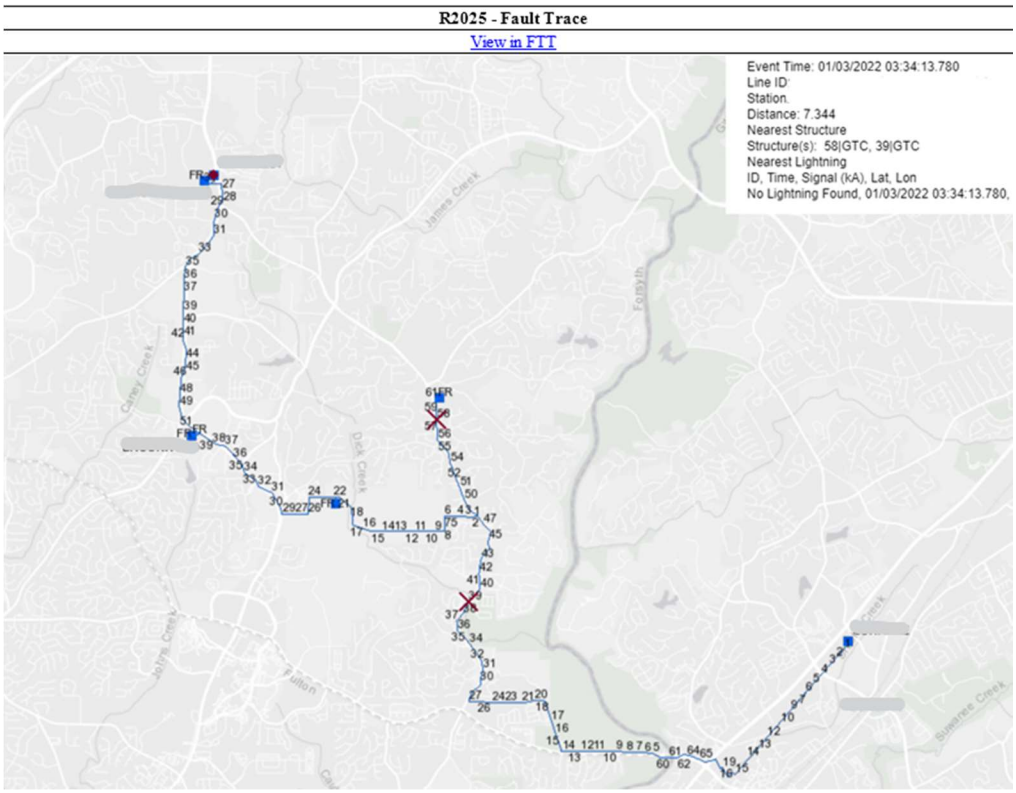
3. MULTI-TAP LOCATIONS CASE STUDY

One of the huge benefits of the Fault Trace Tool is the ability to show multiple faults on a transmission line and its taps, not only a fault on the main transmission line. Seeing all possible fault locations enables more factors to be considered and ruled out regarding where a fault could and could not be.

In the example below, the DFR gave fault information from a substation in the middle of the transmission line. From this location, two possible fault locations are possible on either side of the substation, as seen by the maroon X's near structure 14 and 36-37. Meanwhile, the information box is quick to show the ownership of all three of these poles being GTC. This structure information is a key piece for GTC, as it quickly shows who owns the pole that may have a fault, and which crews should be recommended to troubleshoot the fault. In this example, the GTC patrol found a bird at structure 13, near one of the maroon X's on the map.



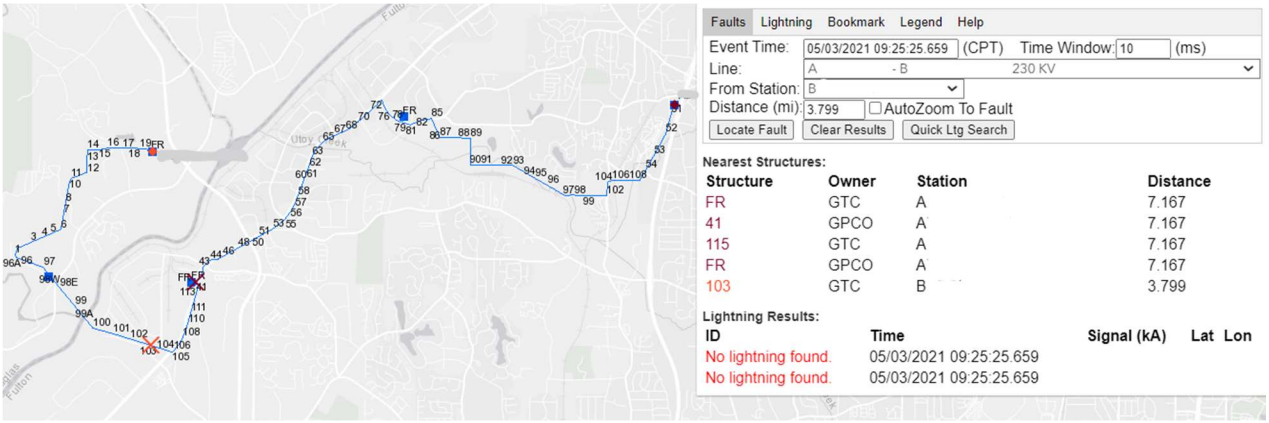
In the example below, there were two locations for the fault from the DFR on the northern end of the transmission line. The first fault could have been at structure 58 on the tap, and the second fault could have been at structure 39 down the main line. The information box shows that both of these structures are owned by GTC, which again gives a quick indication of which crews need to find the outage location. In the end, a green tree fell from off the right of way into the line near structures 36-37, which was within a few spans of the lower X on the line.



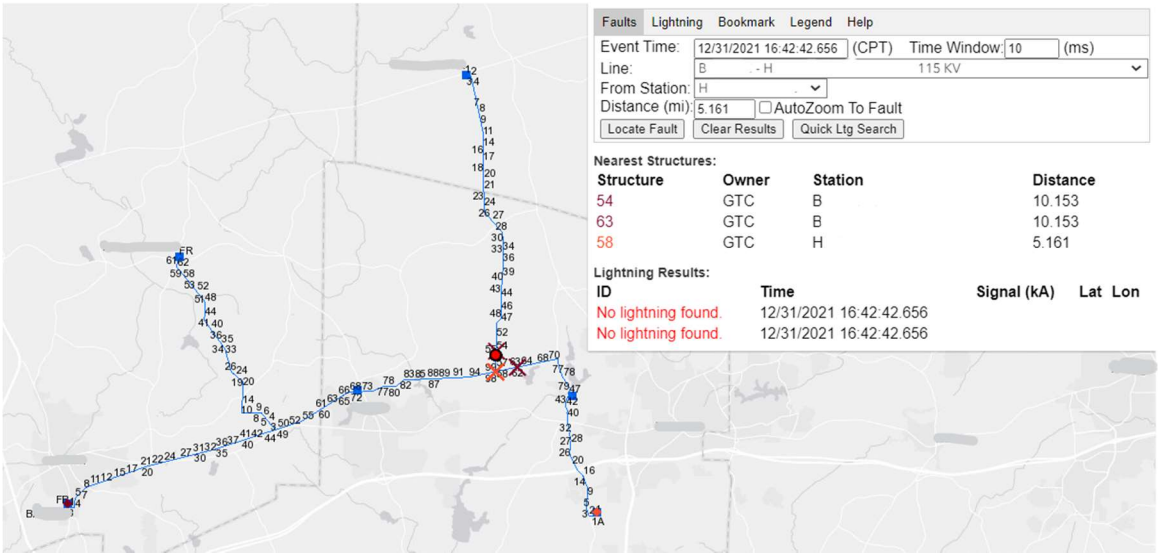
4. DOUBLE ENDED CASE STUDY

Being able to automatically visualize one X on the line from DFR fault data has proven to be very beneficial to our field crews and control center operators. The additional capability of adding DFR or relay information from the other end of the transmission line at the time of the fault increases the understanding of what all available information is showing at the time of an event.

This email came from the "View in FTT" link in the PQ Dashboard email. It opens up the FTT webpage and the first substation is highlighted by a maroon dot, with a maroon X on the line. We manually entered the second DFR distance into the tool, and it is displayed by a red substation dot and red X on the line. The outage was due to a green tree between structures 106-107.



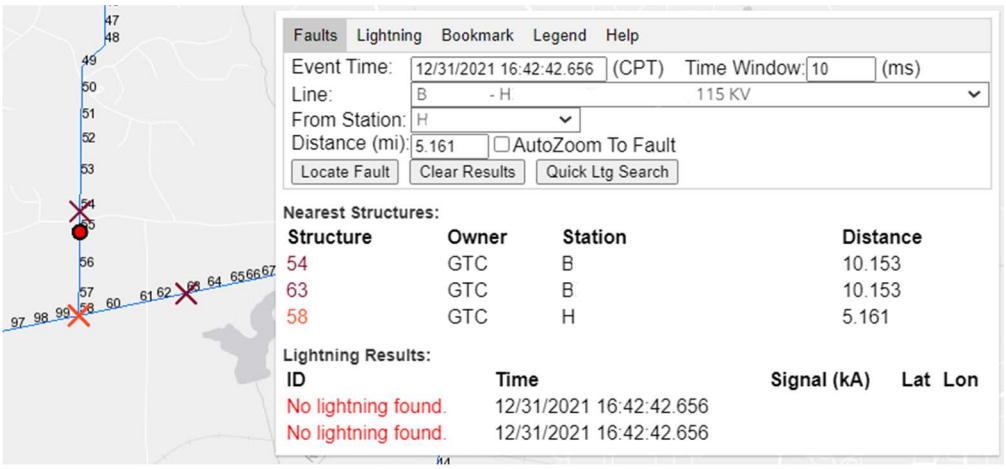
The combination of multi-tap fault location and double ended analysis enables a quick overview of all possible fault locations and a visual narrowing down of locations to one or two most likely spots. In the example below, the DFR email provided the two locations in maroon, and manually entering the DFR distance from the other end provided the red X, which narrowed down the fault location to a few spans on the main transmission line.



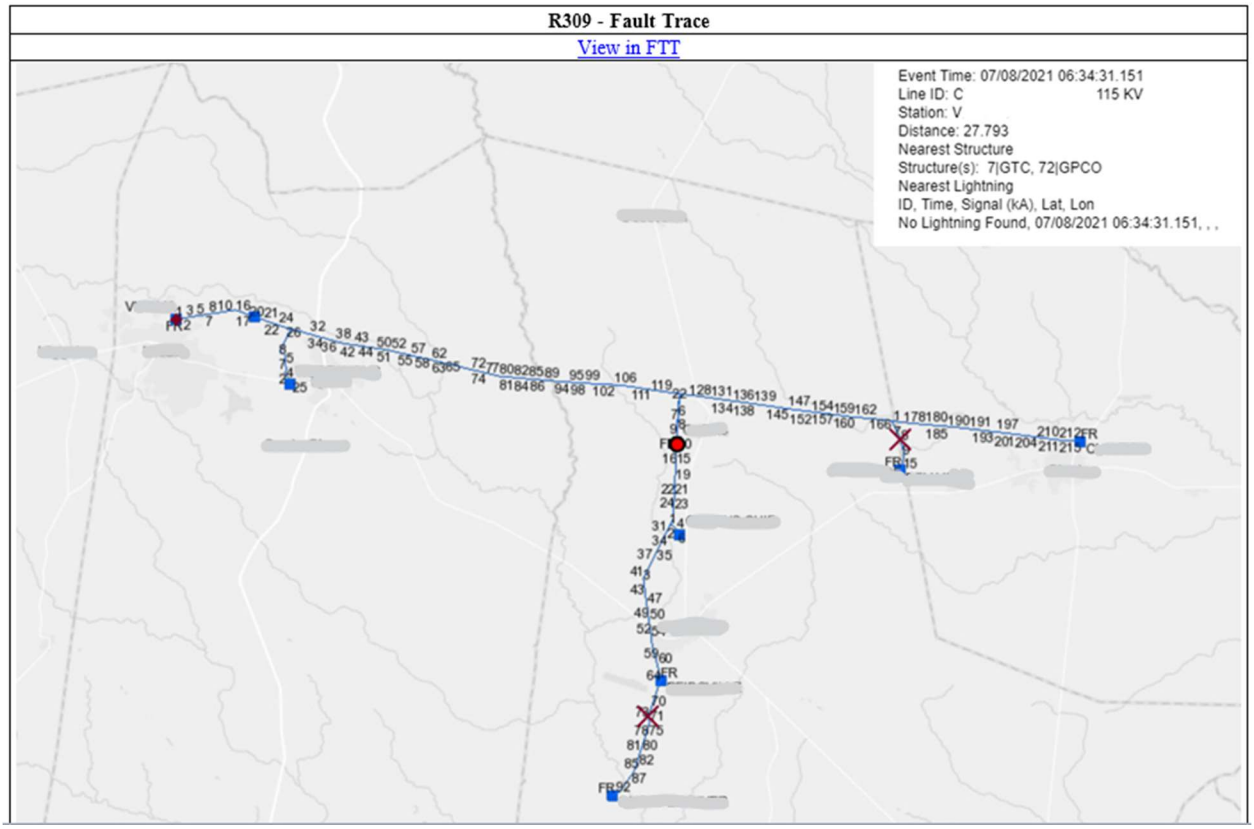
The example above also showcases the benefit of using data from line fault indicators, as discussed below.

5. FAULT INDICATOR CASE STUDY

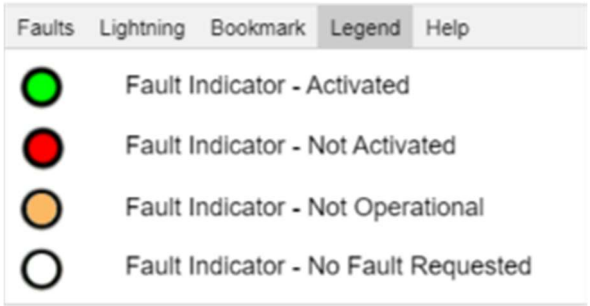
Zooming into the fault locations from the example above, a red circle can be seen on the tap with one X heading north. This red circle gives a quick visual of the status of the Fault Indicator on the line. In this example with multiple maroon X locations it is extremely helpful to see the red Fault Indicators, which means that the Fault Indicators did not see a fault, to show that the tap line to the north did NOT see a fault. This would lead the user to search for a fault cause near the main transmission line maroon X. In this case, a tree was found on the line between structures 61-62 near the main line maroon X.



In the example below, the red Fault Indicator narrows down the fault location to the X on the main line, and shows that the south tap line X is not an actual fault. (Note: this transmission line loops through the substation where the X on the line is at, which is why there are only 2 Xs and not 3). Crews found a snake at structure 163.



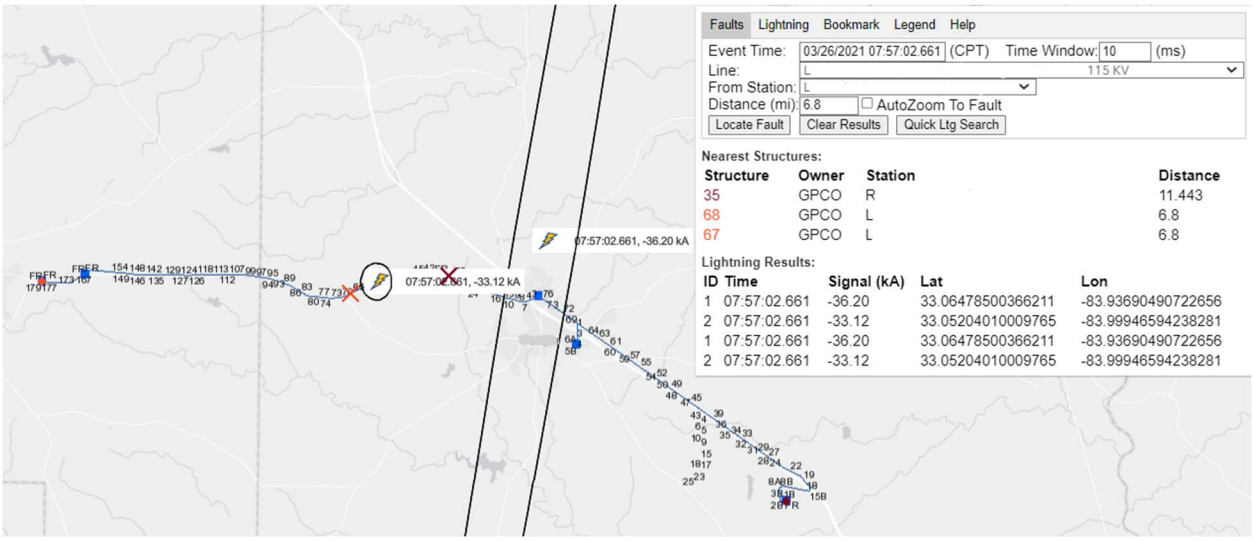
Below is the legend showing what the colors of the Fault Indicators mean. When there is a fault, the indicator turns green. If there was no fault detected, the indicator turns red. There are some Fault Indicators on the system that are not operational due to connection issues, maintenance needs, or other reasons. We chose to still show them with an orange indicator, so that we know where planned maintenance may offer better data for future faults. If there is a fault indicator on the line, but no fault distance was requested, the indicator will stay clear. This is helpful so that a red indicator would not turn into a false negative in situations where no request was made for Fault Indicator status.



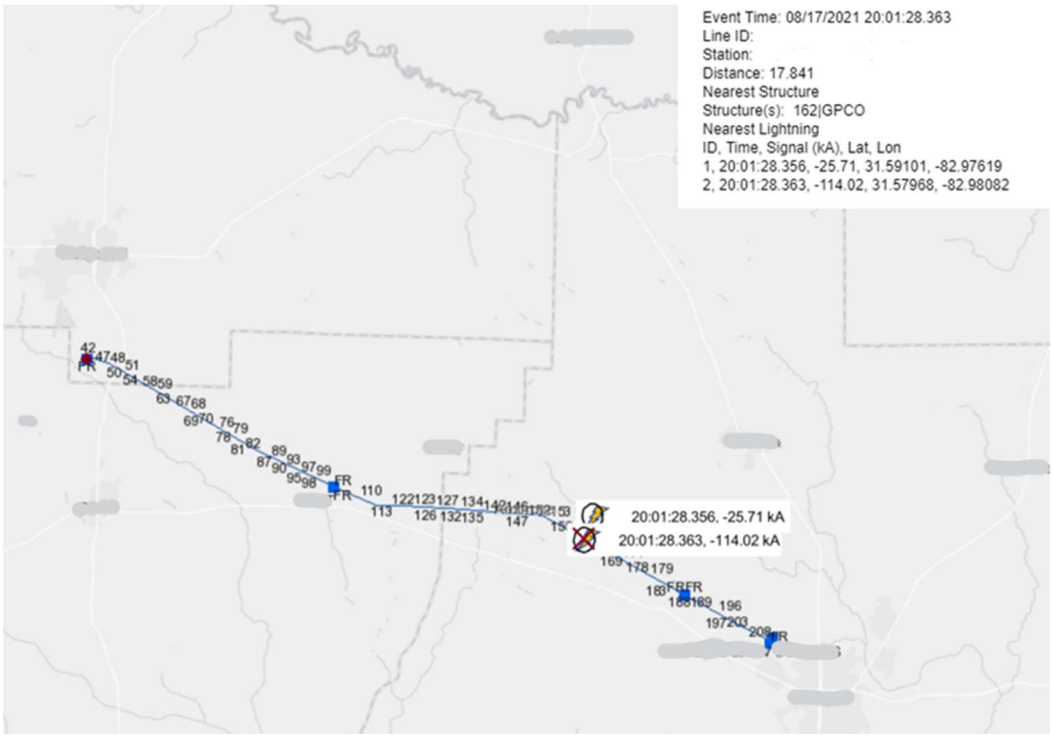
6. FAULTS WITH LIGHTNING CASE STUDIES

In fault maps with lightning strikes as shown below, the smaller the "ellipse of confidence" around the lightning strike, the more confident the lightning software is in the location of the lightning strike, and vice versa. For the FTT example below, the lightning strike on the left has a tiny ellipse, so most likely the lightning strike was near the transmission line. Meanwhile the larger ellipse on the right, where the lightning could have been anywhere within the ellipse, indicates that the lightning strike could have impacted the transmission line, but the confidence of this being the exact location is lower. It would be suggested for crews to patrol the line between the red and maroon X's, especially the structures around the left lightning strike, to look for damage to the line.

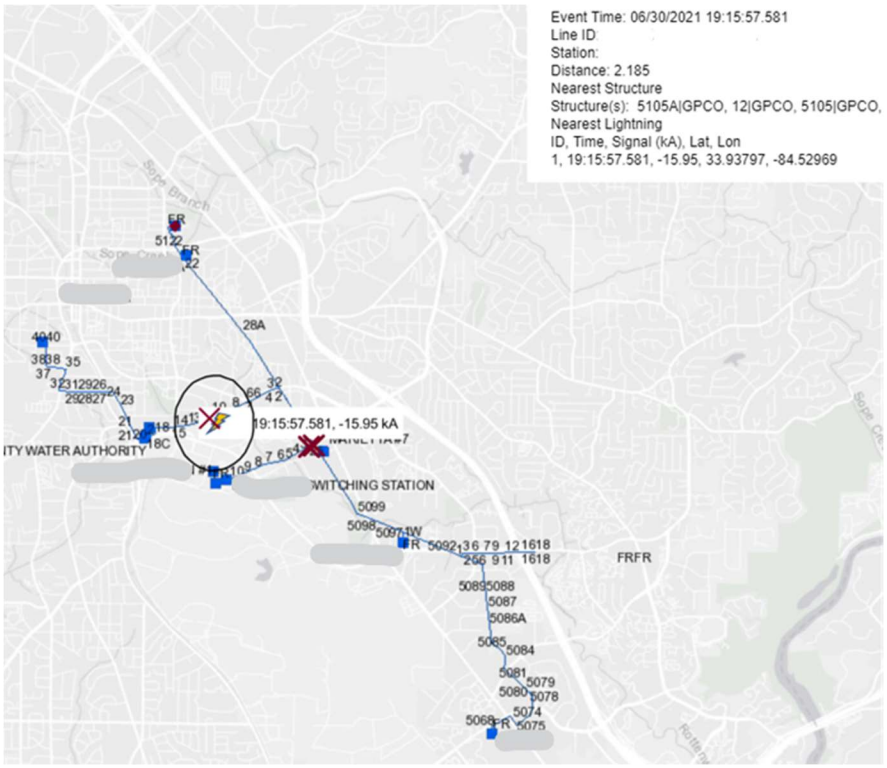
It is also worth noting the details in the Information Box – the nearest structure, who owns the pole, the distance the FTT ran, and the lightning study results – were previously un-viewable before the Fault Trace Tool.



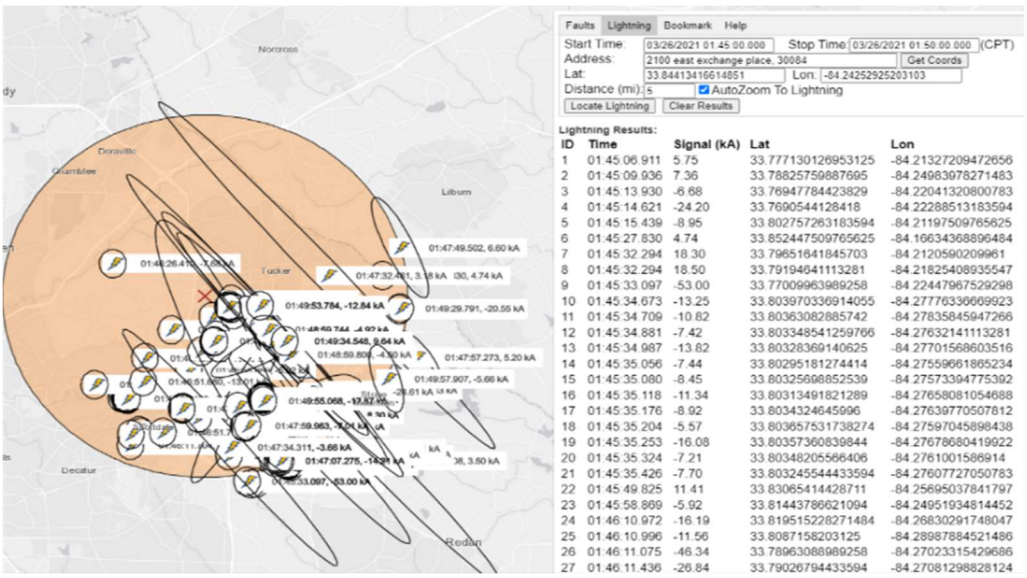
It is beneficial to see all the lightning strikes in close proximity to the transmission line at the time of the fault, so that the field crews have all the information available in a visual map when they go to search for any damage from the lightning strikes. In the example below, there are two strikes close to where the DFR indicated the fault location to be. Since the maroon fault distance X overlaps with one of the lightning strikes, this is the first place it would be recommended to look.



When the lightning strike information is overlaid with a fault map with multiple fault locations, it proves to be another beneficial piece of data to narrow down the probable location of the fault. In the example below, the addition of lightning on the map quickly narrowed down three possible fault locations to one.



Additionally, the Fault Trace Tool has been beneficial for providing a quick response to our EMC customers who ask if there were any lightning strikes during a set time range. For example, we may receive EMC calls requesting information for any lightning strikes the previous Saturday night from 10pm-12am that may have impacted an industrial customer. We are able to use the FTT lightning tool to run a quick analysis of any lightning on that date during that time range at either an address or latitude and longitude coordinates. In the example below, we entered an address and ran a 5 minute lightning study to see what faults were in the area. This was during a heavy lightning storm, so during this 5 minute window, there were over 30 lightning strikes within a 5 miles radius of the address.



ID	Time	Signal (kA)	Lat	Lon
1	01:45:06.911	5.75	33.777130126953125	-84.21327209472656
2	01:45:09.936	7.36	33.78825759887695	-84.24983978271483
3	01:45:13.930	-6.68	33.76947784423829	-84.22041320800783
4	01:45:14.621	-24.20	33.7690544128418	-84.22288513183594
5	01:45:15.439	-8.95	33.802757263183594	-84.21197509765625
6	01:45:27.830	4.74	33.852447509765625	-84.16634368896484
7	01:45:32.294	18.30	33.79651641845703	-84.2120590209961
8	01:45:32.294	18.50	33.79194641113281	-84.21825408935547
9	01:45:33.097	-53.00	33.77009963989258	-84.22447967529298
10	01:45:34.673	-13.25	33.803970336914055	-84.27776330669923
11	01:45:34.709	-10.82	33.80363082885742	-84.27835845947266
12	01:45:34.881	-7.42	33.803348541259766	-84.27632141113281
13	01:45:34.987	-13.82	33.80328369140625	-84.27701568603516
14	01:45:35.056	-7.44	33.80295181274414	-84.27559661865234
15	01:45:35.080	-8.45	33.80325698852539	-84.27573394775392
16	01:45:35.118	-11.34	33.80313491821289	-84.27658081054688
17	01:45:35.176	-8.92	33.8034324645996	-84.27639770507812
18	01:45:35.204	-5.57	33.803657531738274	-84.27597045898438
19	01:45:35.253	-16.08	33.80357360839844	-84.27678680419922
20	01:45:35.324	-7.21	33.80348205566406	-84.2761001586914
21	01:45:35.426	-7.70	33.803245544433594	-84.27607727050783
22	01:45:49.825	11.41	33.83065414428711	-84.25695037841797
23	01:45:58.869	-5.92	33.81443786621094	-84.24951934814452
24	01:46:10.972	-16.19	33.819515228271484	-84.26830291748047
25	01:46:10.996	-11.56	33.8087158203125	-84.28987884521486
26	01:46:11.075	-46.34	33.78963088989258	-84.27023315429686
27	01:46:11.436	-26.84	33.79026794433594	-84.27081298828124

As mentioned in the introduction of this paper, GTC rolled out an EMC Lightning Viewer, primarily so our EMC customers can run this same lightning range tool overlaid on their GIS distribution systems, and be able to see any lightning strikes within 1 mile of their distribution circuits.

7. SUMMARY

The Fault Trace Tool project proved to be very beneficial to GTC and our ability to visualize what our data inputs are showing us at the time of system faults. We continue to strive to improve the tool with user input ideas and learning from other utilities.

This paper ends with one last example that combines almost all of the tools previously overviewed. The fault below placed a fault location X on the main transmission line and one of the small taps. Additionally, lightning was in the area and a fault indicator was on the line. The combination of an X on the line, lightning ellipse, and an activated fault indicator quickly narrowed down the fault location to the tap line, showcasing how the visualization of data provides quick fault analysis and response opportunities. We are excited about this tool and appreciative of the opportunity to share it at the FDA conference.