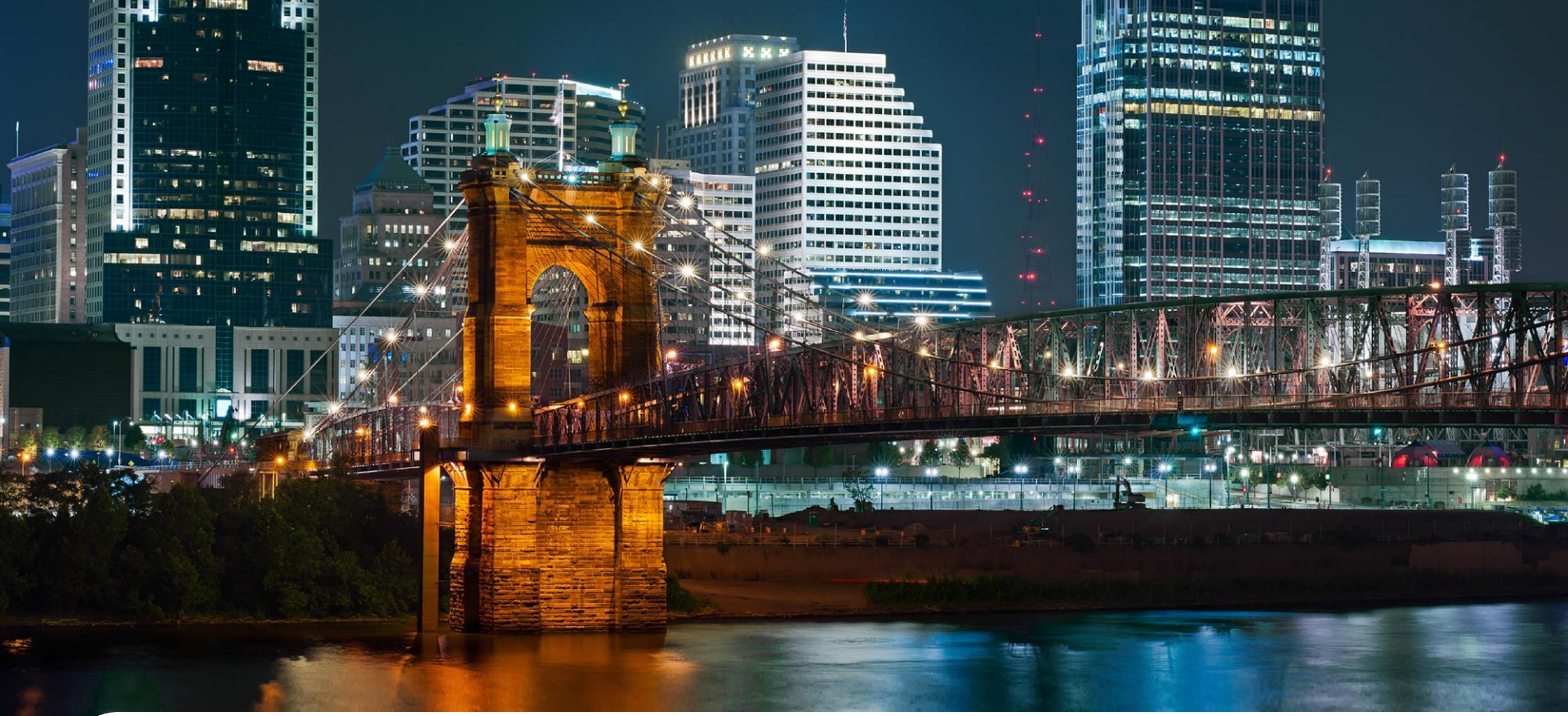

OpenXDA: Double-Ended DTF Calculation

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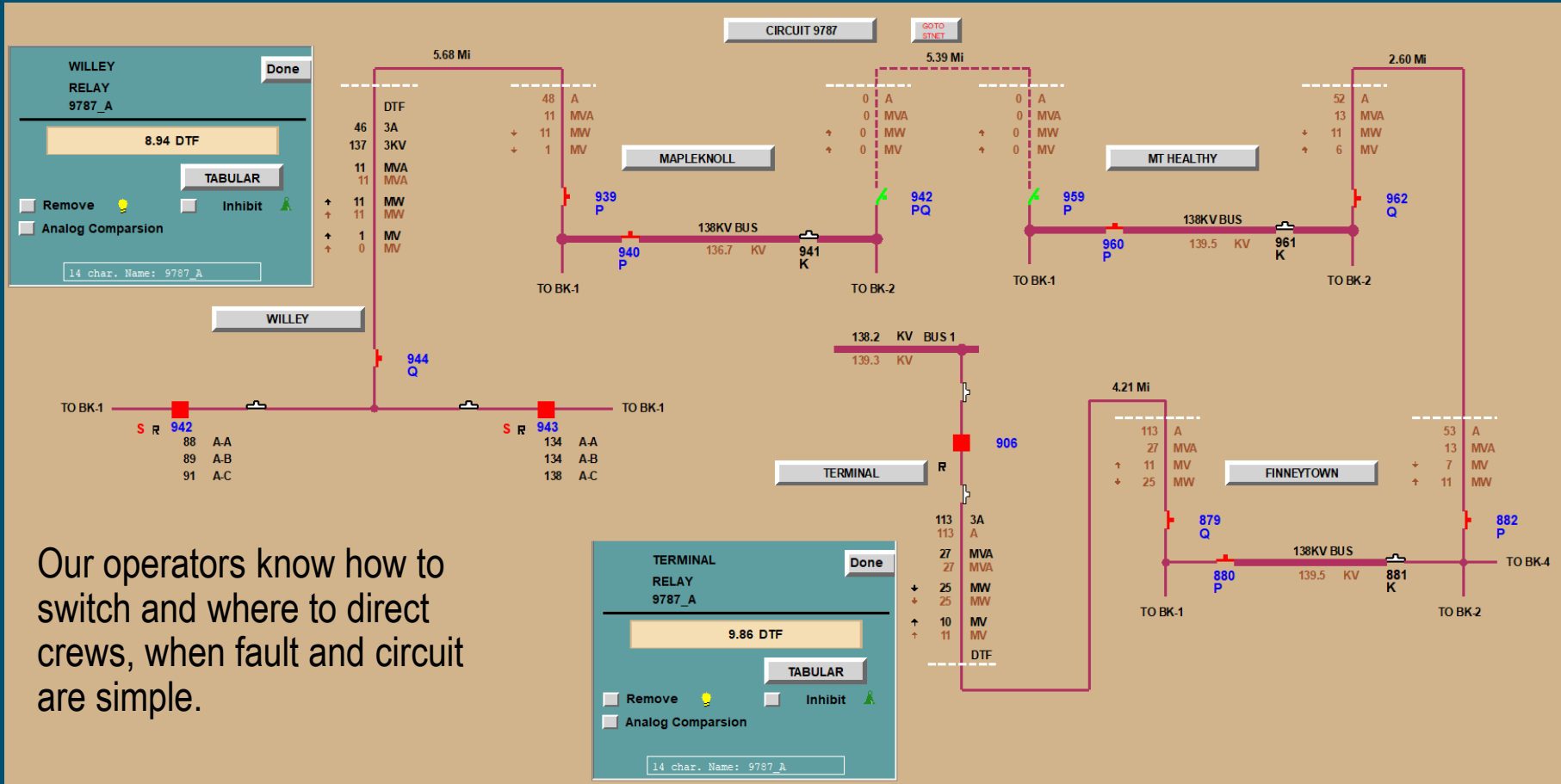
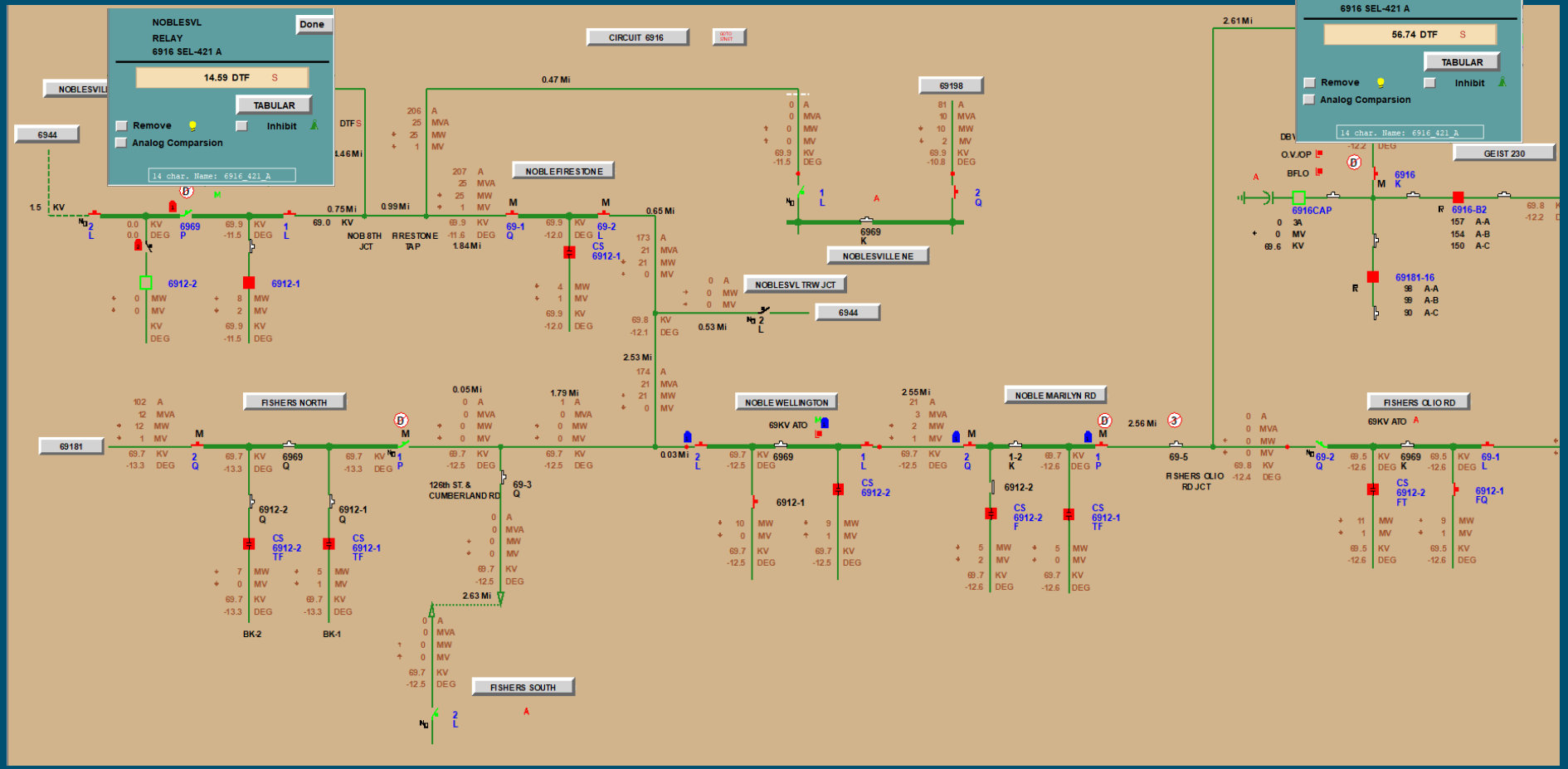
DUKE ENERGY®

In DEM, EMS brings back single-ended DTF values from the line relays



Our operators know how to switch and where to direct crews, when fault and circuit are simple.

Example of a more complex circuit



Duke Fault Labs very helpful with more complex fault situations

- We must account for issues causing error in single-ended DTF calculations:
  - Infeed and Outfeed
  - Fault Resistance
  - Mutual Coupling
  - Other inaccuracies associated with ground faults
- The use of Double-Ended Negative Sequence DTF (DENSDTF) calculations does this for us, allowing allows us to pin-point the location of the fault.
- Thus, our focus on evaluating the double-ended calculations in OpenXDA

OpenXDA DENSDTF calculations

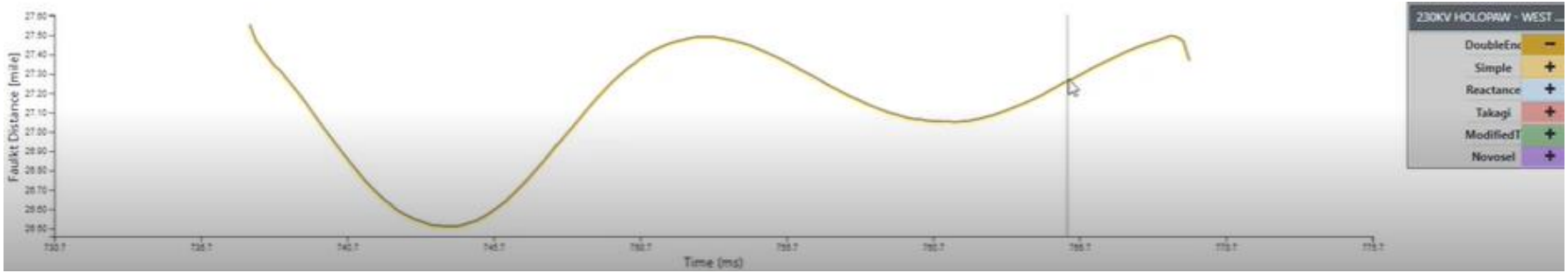
Our understanding of how OpenXDA performs DENSDTF *:

- The software selects one cycle of data from the remote terminal, specifically that with the maximum summed magnitude of currents
- The negative sequence current and voltage phasors are calculated for the representative cycle selected from the remote terminal
- A double-ended negative sequence DTF is calculated for each sample of the local terminal waveform based on the remote terminal phasors
- The DTF algorithm used is what we refer to as the synchronized calculation, not the quadratic calculation

* *See Recording @ 1:47:55*

This approach appears to assume a consistent fault

- The DENSDTF calculations require the faulted cycles to be matched up in time
- As a fault progresses, its characteristics change and so do the phasors
- The calculation should not use phasors from different points in time
- The approach taken will provide one proper result, that being the one with synchronized phasors,
  - Provided the fault is still double-ended at that time.
  - A full DTF curve is shown but not annotated
  - Given the curve, we are not sure which point is the accurate one
  - Results for complex faults will be misrepresented



Fault phasors vary in a wide number of scenarios

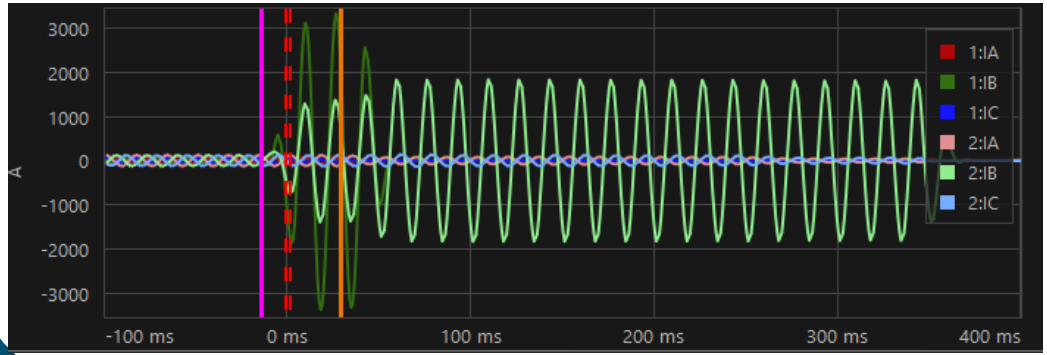
Such as with:

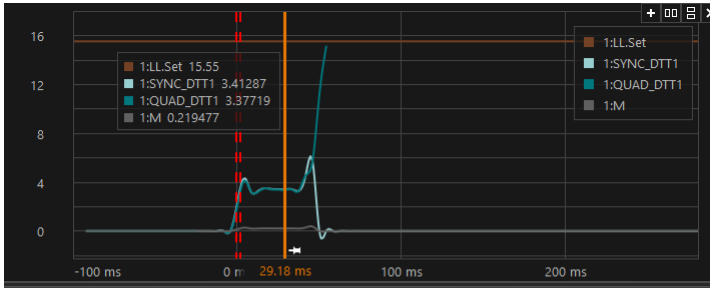
- Varying fault resistance
- Sequential clearing
- Evolving faults
- Tap faults

OpenXDA does not properly evaluate tap faults

- Single-ended DTF are not accurate for tap fault, and neither are double-ended DTF
- DENSDTF will actually calculate the distance to the tap (DTT),
- And will not determine the distance down the tap (DDT) to the fault location.

Additional calculations are required to locate tap faults.

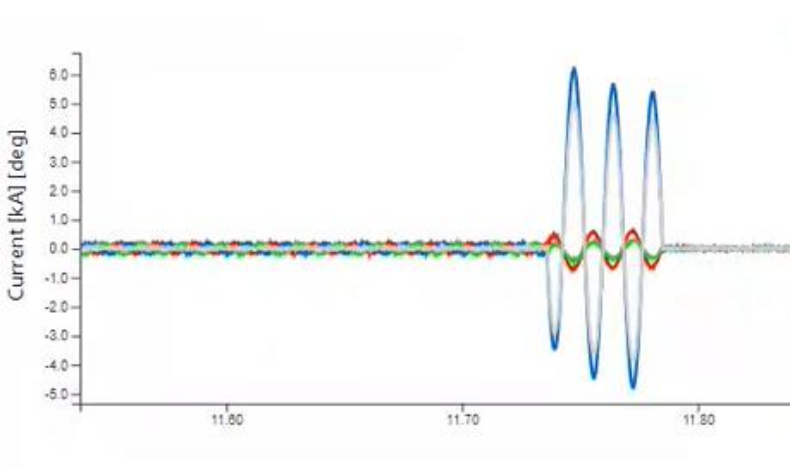


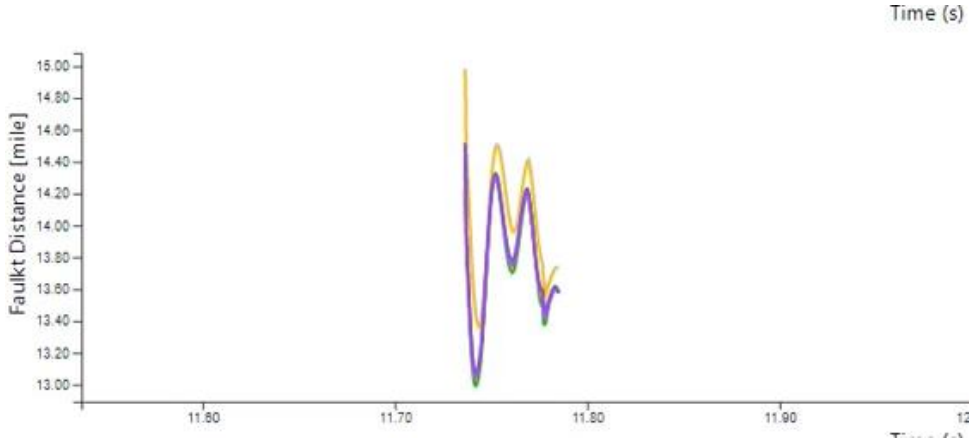


DFR signals contain DC offset due to the X/R of the system

OpenXDA does not filter out the DC component of the current and voltage signals

- This creates a large oscillating error signal on the DTF curves
- The DC should be removed from the AC signals prior to processing
- This is why filtered 60Hz records are used in our calculations





Additional concerns:

- The high degree of required system configuration.
  - Managing the data associated with each line section (length, %Z, connectivity, etc.)
  - Mapping each device signal
- Managing fault records with incorrect times. Not all Duke devices are sync'd with a satellite clock.
- Identifying a structure from the calculated DTF/DTT/DDT results
- Need to perform negative sequence DTF calculations on three terminal lines