

# The Time is Now for DFR Monitoring of Distribution Substations

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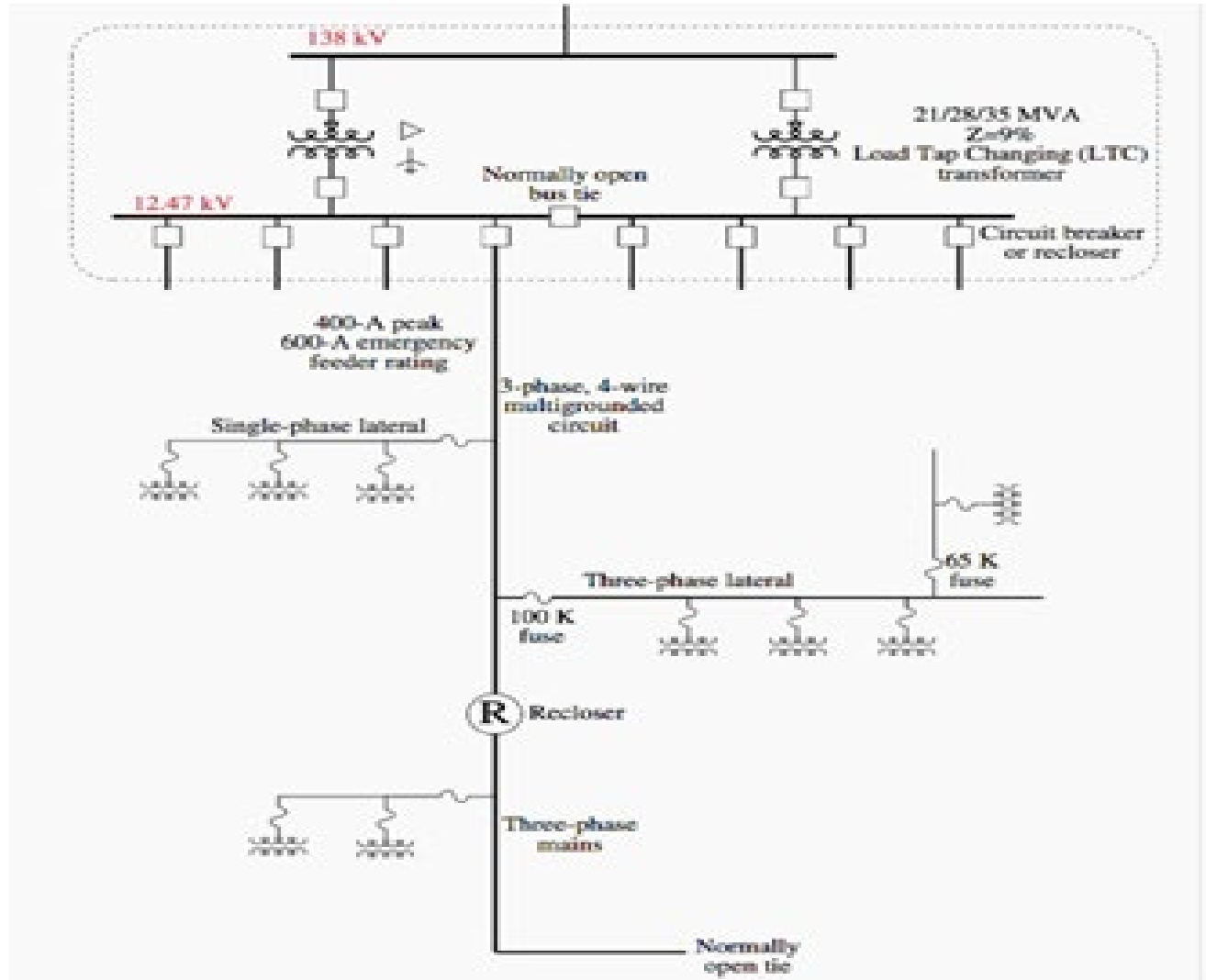
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- The Good Old Days
  - 1980's Distribution Systems
  - Inconsequential impact
- The New World Order
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- The Value of DFR's
  - Multi-function Ultra-versatile asset
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- Conclusion
  - The time is now for DFR Monitoring of Distribution Substations

# The Good Old Days - 1980's Distribution Systems

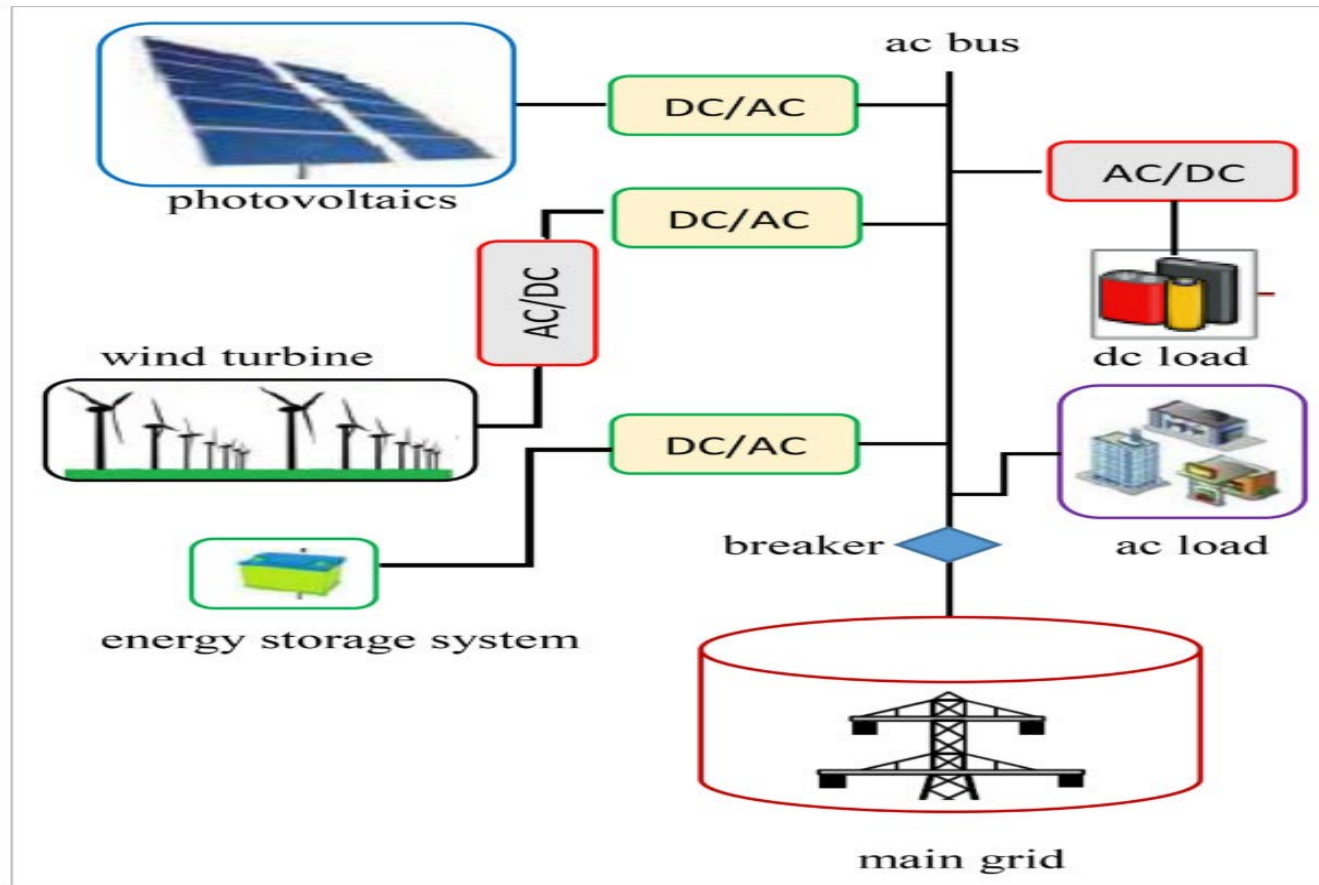
## Inconsequential impact



## The Good Old Days - 1980's Distribution Systems Inconsequential impact

- Ah, the simple, olden days of Distribution Systems. A substation feeder breaker, with a meandering countryside, radial feeder, containing a number of down-stream reclosers, maybe voltage regulators, shunt capacitors, and fused-lateral circuits...Remember those days? Missed those good old days?
- Everything was fairly simple then... However, although simpler, analysis and troubleshooting of disturbances in these legacy systems, was often-times difficult, due to the lack of disturbance recording capabilities, as these medium-voltage assets were typically not worthy of the capital investment associated with high-speed DFR's, mainly due to the fact that their overall impact on the integrity and reliability of the Grid, was minimal to non-existent.

# The New World Order - 2020's Distribution Systems Essential Infra-structure

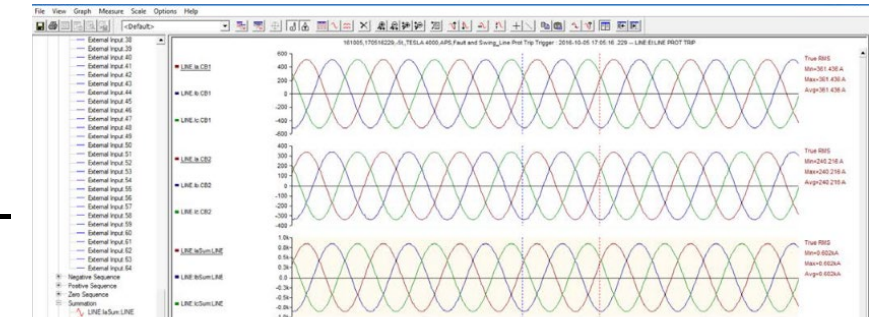


## The New World Order - 2020's Distribution Systems Essential Infra-structure

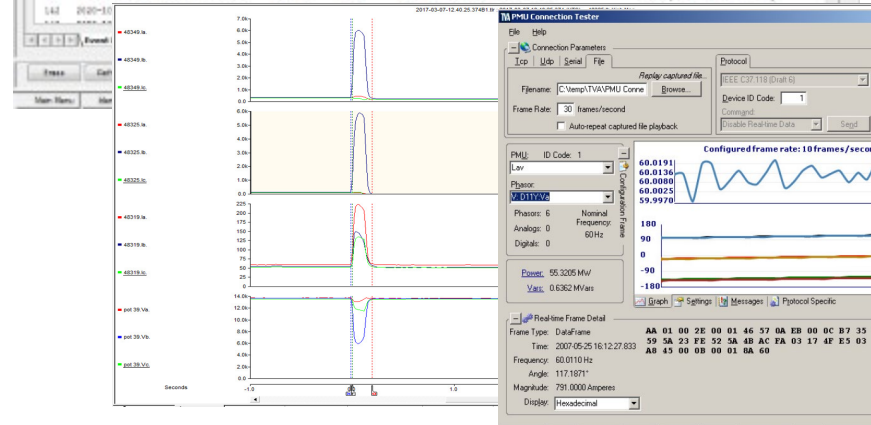
- Nowadays, we have a very exciting life for any engineer involved in the planning, analyzing, operations and/or maintenance of these modern distribution networks.
- The mere attempt of quantifying the level of complexity in all facets of a modern distribution system, whether in terms of planning, operating, maintaining and/or analyzing, of the day-to-day operations, as well as short and long-range operational and planning horizons, is actually a very challenging exercise in and of itself...
- How do we expect to evaluate and resolve the incredibly complex and varied assortment of issues that will be part of the daily operations of these assets, without the capability of capturing high-volume amounts of high-speed operational and/or disturbance data?

# The Value of DFR's Multi-function Ultra-versatile asset

1. High Speed Oscillography recording (high capacity, multi-seconds)
2. Sequence of Events recording (1000 + events/day)
3. Low Speed RMS recording (high capacity, multi-minutes)
4. Continuous RMS Data recording
5. Seasonal RMS Trend recording
6. PMU streaming
7. IEC 61850 GOOSE (some available in SV versions also)
8. Power Quality recording
9. Centralized, Server-based data retrieval and archiving

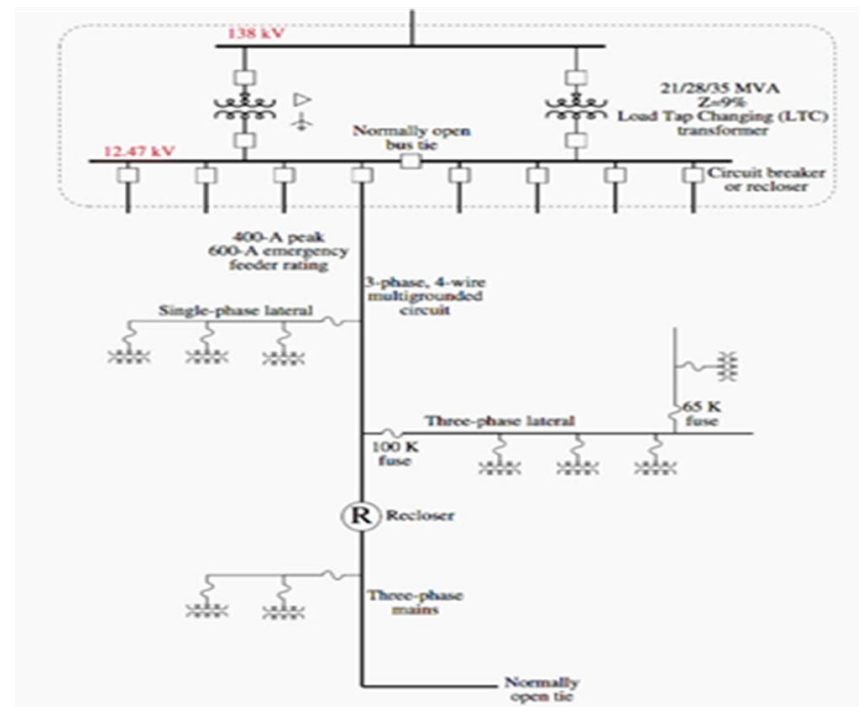


Date	STC Time	STC Offset	Sequence Name	Event ID	Event	Event Quality
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1/18	2020-10-13 15:18:07.000	-05:00	SE1Phase	SE1-002/Robust 1-7% High Mag.		0002 1000 0000 1000 0011
1/19	2020-10-13 15:18:26.885	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE13	Swarm	0000 1000 0000 0000 0000
1/20	2020-10-13 15:18:26.884	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE09	Swarm	0000 1000 0000 0000 0000
1/21	2020-10-13 15:18:26.884	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE08	Swarm	0000 1000 0000 0000 0000
1/22	2020-10-13 15:18:26.885	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE07	Swarm	0000 1000 0000 0000 0000
1/23	2020-10-13 15:18:26.882	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE06	Swarm	0000 1000 0000 0000 0000
1/24	2020-10-13 15:18:26.883	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE05	Swarm	0000 1000 0000 0000 0000
1/25	2020-10-13 15:18:26.882	-05:00	SE1Phase	0008-NOUGAR-G-Featr7_EE04	Swarm	0000 1000 0000 0000 0000
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## The Value of DFR's - Multi-function Ultra-versatile asset

- When the above list of data acquisition functionalities, is coupled with the ability to monitor a large number of system elements (transformers, busses, feeders, capacitor banks, etc.) all at once, with the use of one monitoring device, the end-user should be able to have the ability to evaluate the vast majority (if not all) of disturbances and anomalies in the distribution grid.





## The Value of DFR's - Multi-function Ultra-versatile asset

- We need to keep in mind that associated with the exponential increase in the complexity and variety of the distribution grid elements, will also come a very complex set of element-element and system-system interactions, hence the legacy approach of only reviewing/evaluating the behavior of the one element that started/caused the anomaly, will very likely not suffice, as many distribution system assets will be interacting with one-another, as part of their normal operation.
- The availability of high-volume (DFR) system data, which is also synchronized to high-precision time sources, will be a critical component in ensuring optimal distribution systems operational and reliability indices.

## The Value of DFR's - Multi-function Ultra-versatile Legacy Electro-mechanical Relay Sites

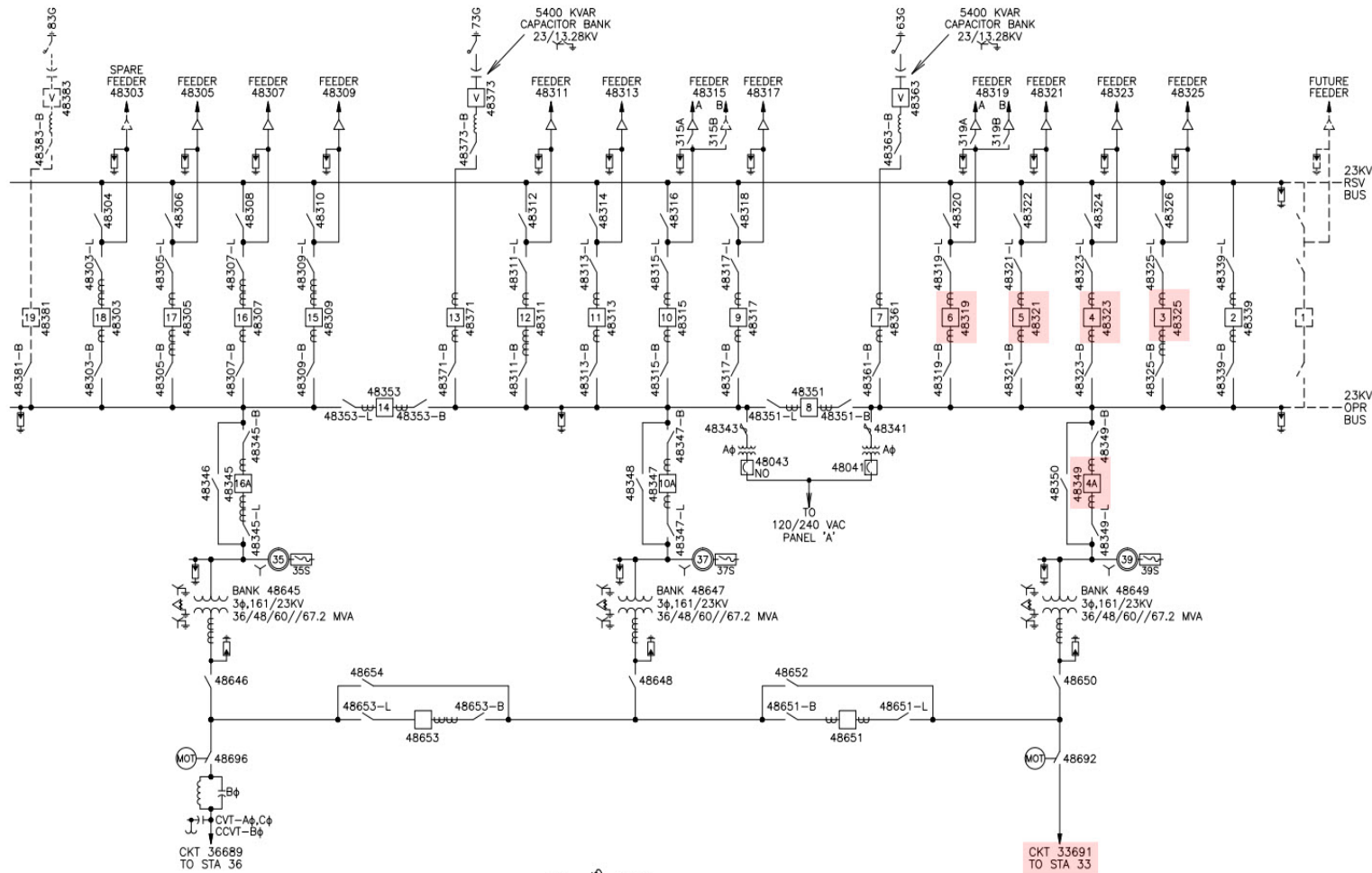
- Another area where DFR's can bring unquestionable value to the operations and disturbance analysis of distribution systems, is in legacy distribution substations where protection devices are still of the electro-mechanical type, where system disturbance data acquisition is very likely non-existent.



## The Value of DFR's - Multi-function Ultra-versatile Legacy Electro-mechanical Relay Sites

- The author, presents a case where a customer with such a substation (one equipped only with electro-mechanical relays), was experiencing frequent, random feeder faults, that they were not able to understand/resolve. They temporarily installed a portable DFR, and wired it to monitor a number of feeders in the distribution bus, in an attempt to collect sufficient data to troubleshoot the issue.
- Below is the substation's simplified one-line drawing.

# The Value of DFR's - Multi-function Ultra-versatile asset Legacy Electro-mechanical Relay Sites



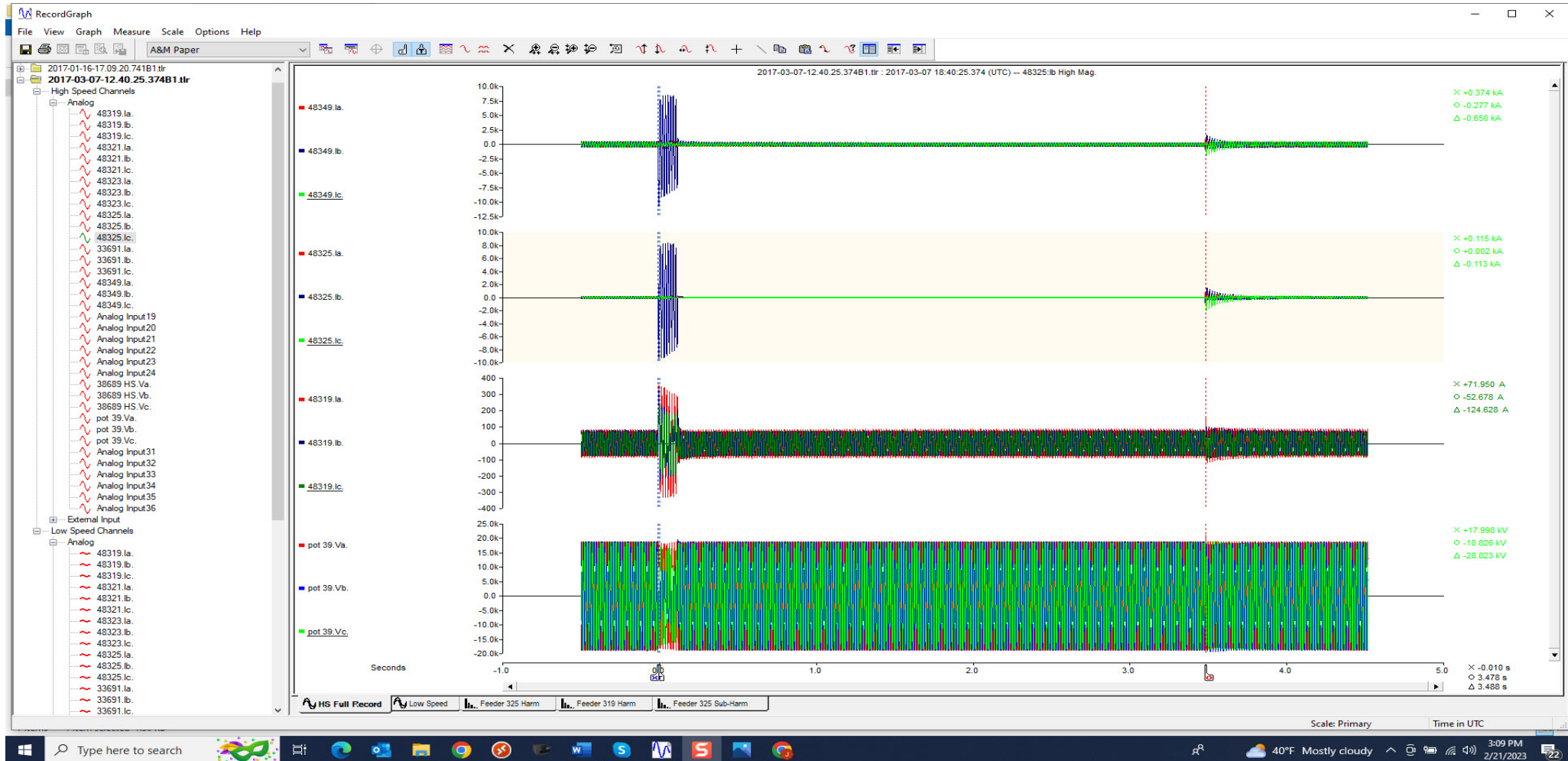
## The Value of DFR's

### - Multi-function Ultra-versatile asset Legacy Electro-mechanical Relay Sites

- Highlighted elements were the one's being monitored. Over a period of a few months, a number of events were captured/recorded.
- A sampling of the various data types and their associated graphical views are presented below, as an example of the granularity that can be used in evaluating system operations and/or responses to anomalous events.
- The goal for sharing this (typical) case of a substation equipped with electro-mechanical relays, with a sampling of DFR captured disturbance data, is not to show how the root-cause of their events was discovered, but instead to highlight the inherent and significant value that high-speed, high-accuracy, and diverse data collection, contributes to the overall operation and maintenance of a distribution system.

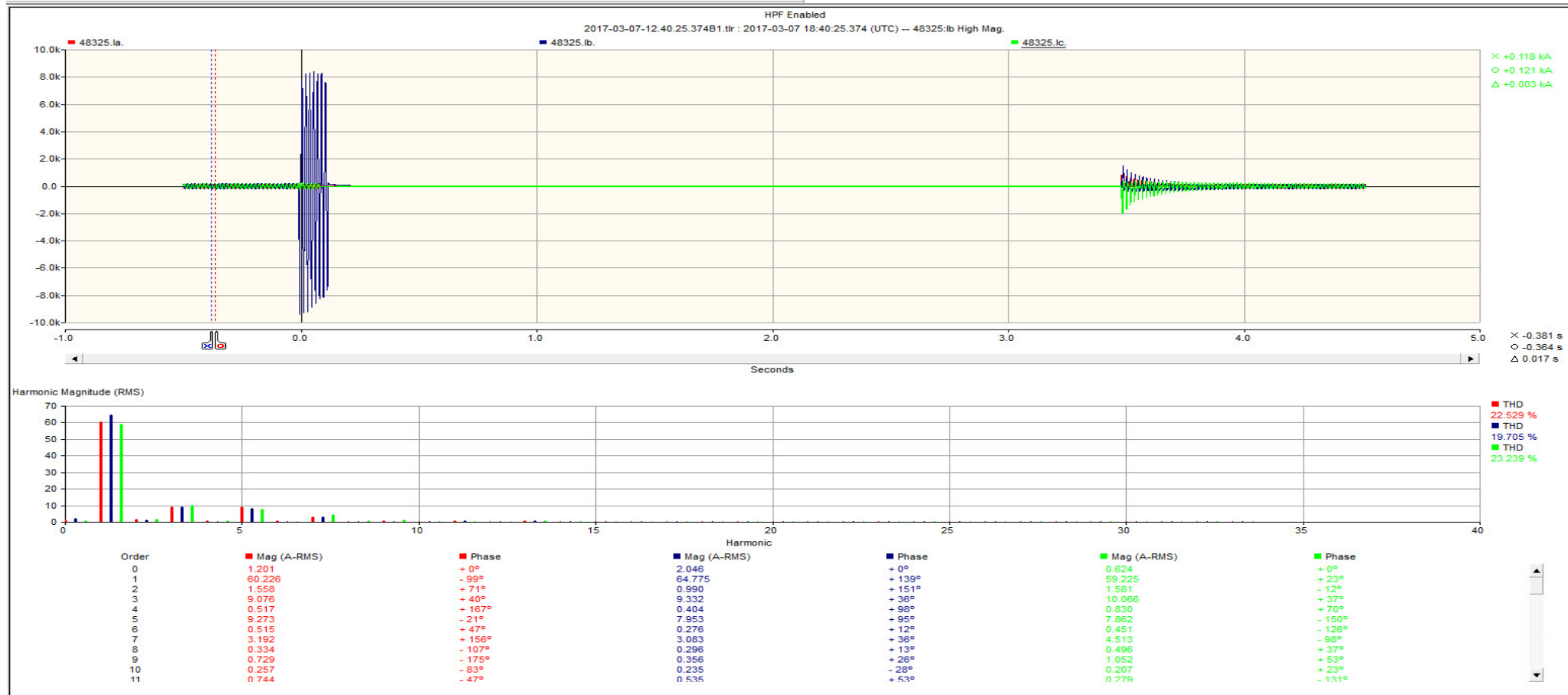
# The Value of DFR's

- Multi-function Ultra-versatile asset
- Legacy Electro-mechanical Relay Sites
- High-speed Oscillography



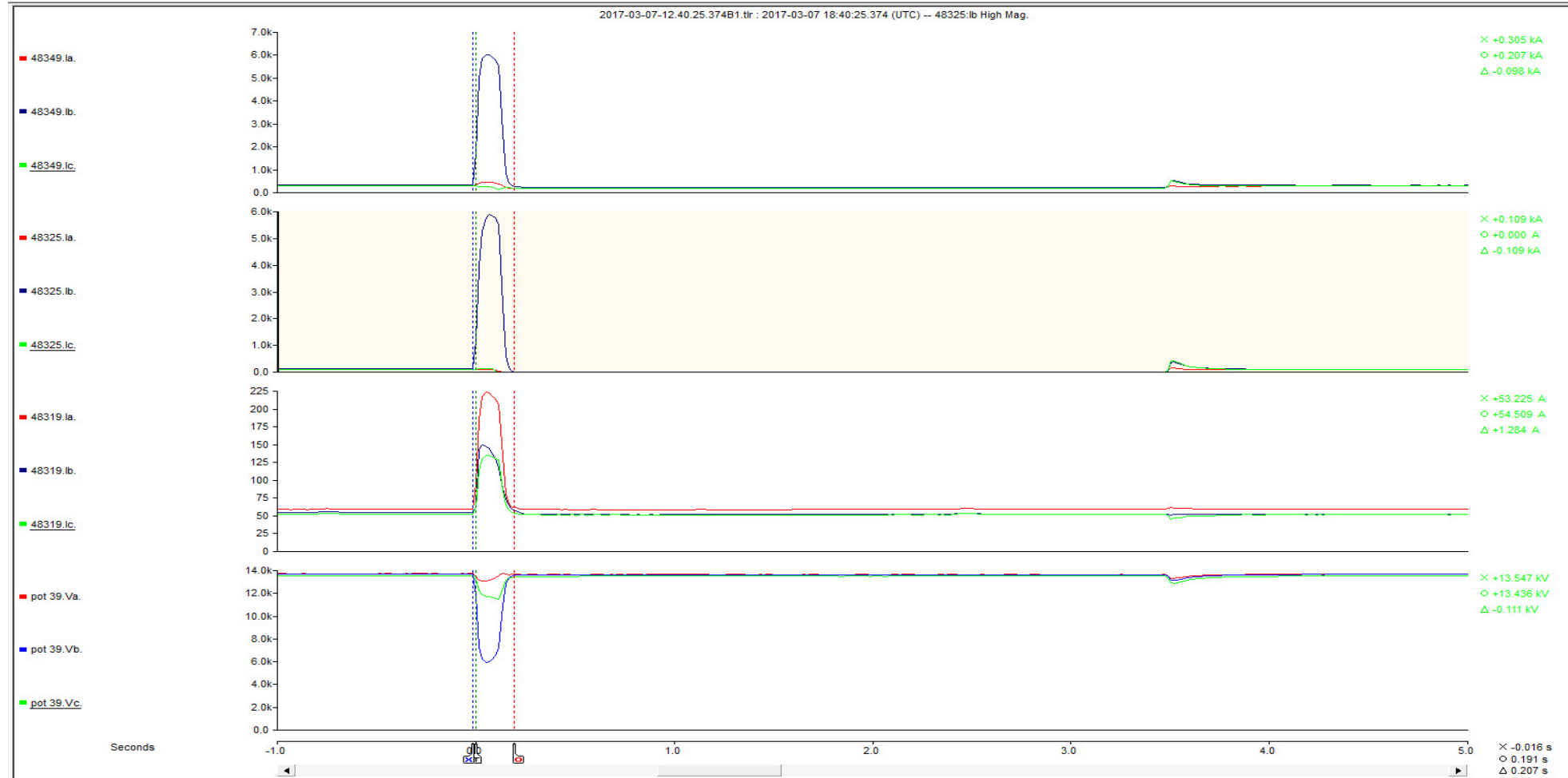
# The Value of DFR's

- Multi-function Ultra-versatile asset
- Legacy Electro-mechanical Relay Sites
- Harmonic Content



# The Value of DFR's

- Multi-function Ultra-versatile asset
- Legacy Electro-mechanical Relay Sites
- Low-speed RMS





## The Bottom Line - Truly Cost-justified Cost vs Functionality

- What about the economic feasibility of DFR's in distribution class systems? A typical DFR may cost somewhere in the area of \$25K, an apparent first impression, steep investment. However, let's dissect the investment in terms of its functionality versus cost, and in terms of its cost per feeder-element basis.
- From a Function versus Cost perspective, and assuming the use of all of the device's capabilities listed in "The Value of DFRs" section, we arrive at a cost of \$25K divided (equally for the sake of simplicity) by 9 capabilities, for an estimated net cost/function of \$2,800. Basically, a multi-function device, providing real-time PMU data, high-speed Oscillography disturbance data, 61850 GOOSE and MMS capability, standard SCADA DNP3 functionality, Sequence of Events data, Continuous Data Recording, and 90-day RMS Trending data, all in one box. A pretty good value in any estimation.

## The Bottom Line - Truly Cost-justified Cost per Feeder/Element

- From a Cost/Feeder perspective, depending of the actual substation's topology/layout, a single DFR could easily monitor ten (10) Feeders and two (2) Buses, a total of 12 elements, resulting in an estimated net cost of about  $\$25\text{K}/12 = \$2,100/\text{element}$ .
- Let the user not ignore or minimize the value that DFR data will have, when the complexity of the issues that will be experienced in our modern Distribution Networks starts to reflect the complex nature and variety of its elements.
- This engineer and author, believes that the complexity of future Distributions Grids will equal and/or surpass the complexity of the Transmission level systems.

## Conclusion

- The time has indeed come, for DFR monitoring of Distribution Substations, from a financial, operational, and system analysis perspectives.