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# Framework for Post-Facto Analysis of Wide-area Power System Disturbances and Events

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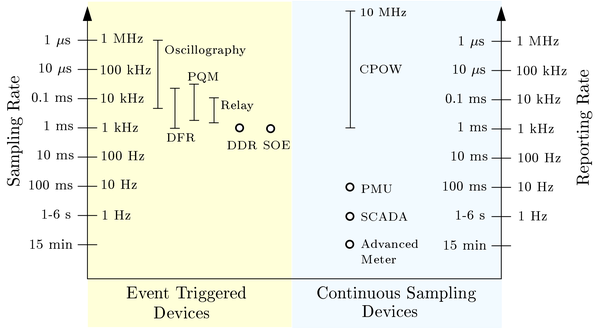
## Introduction

- **Event triggered devices**: e.g. DFR, SoE, etc.
- **Continuous sampling devices:** e.g. PMU, SCADA, etc.




DFR: digital fault recorder — SOE: sequence of events
DDR: dynamic disturbance recorder — CPOW: continuous point-on-wave
PQM: power quality monitoring — PMU: phasor measurement unit
SCADA: supervisory control and data acquisition

Fig. 1: Recording Devices in a Power System (adapted from [1]).

**Post-mortem analysis** of wide-area power system disturbance ⇒ **collate diverse data**.

## Example Dataset: Major Power System Disturbance

**Mumbai blackout of 12th October 2020** [2]:

**Key observations:**

1. DFRs did not comply **naming conventions**. (IEEE C37.232-2011 (COMNAME) & C37.239-2010 (COMFEDE).
2. Not all DFR were time-synchronized.
3. **Vertical scalings** differed in DFR. (The scalings are inferred from SCADA and PMU data).

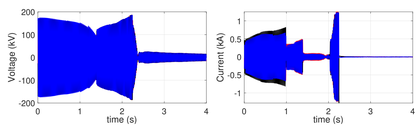



Fig. 2: A typical line trip DFR (Salsette 220 kV line).

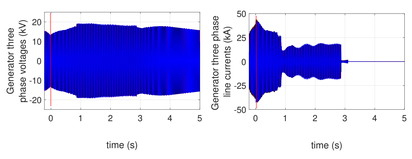



Fig. 3: A typical generator DFR (Trombay unit-5).

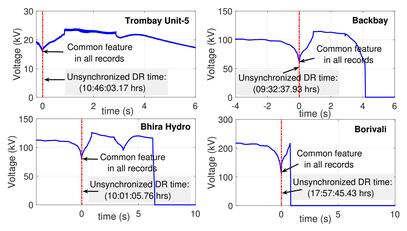



Fig. 4: Common feature in the records for alignment.

COMNAME: common format for naming time sequence data files; COMFEDE: common format for event data exchange.

## UI for Semi-automatic approach

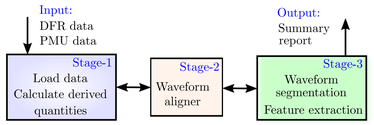



Fig. 5: Framework of the user interface.

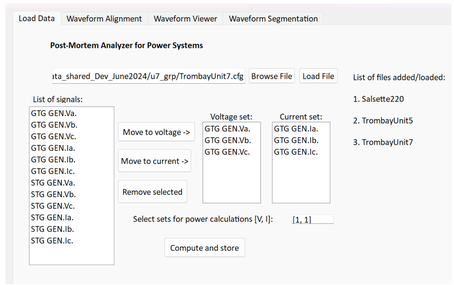



Fig. 6: Data loading and derived quantity evaluation UI page.

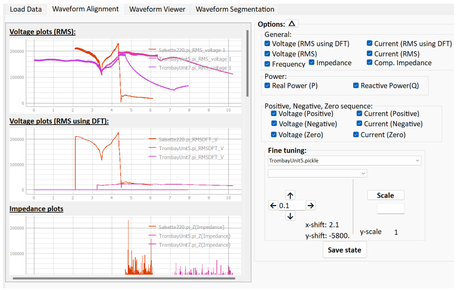



Fig. 7: Waveform alignment page of the UI.

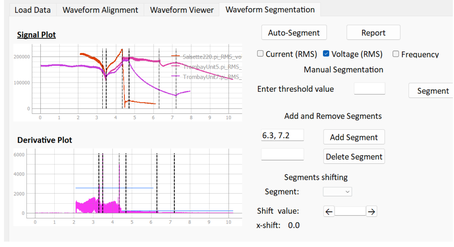



Fig. 8: Waveform segmentation UI stage.

## Outcome of the analysis

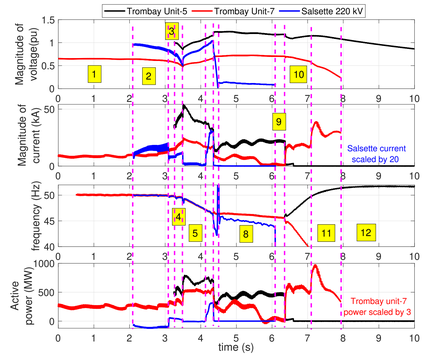



Fig. 9: Segmentation of the time-aligned waveforms.

Table 1: Feature table for segments 5 and 8 of Fig. 9.

| Quantities | Features | Seg. | Waveforms: Trombay U5 | Trombay U7 | Salsette 220 kV |
|---|---|---|---|---|---|
| Voltage Magnitude | Trend | 5 | Increasing | Increasing | Increasing |
| | | 8 | Flat profile | Flat profile | Flat profile |
| | Correlation (PCC) | 5 | Reference (1) | Correlated (0.99) | Correlated (0.99) |
| | | 8 | Reference (1) | Uncorrelated (0.25) | Correlated (0.96) |
| | $V_{nf}$ % | 5 | 1.79 | 2.53 | 1.82 |
| | | 8 | 4.1 | 4.81 | 0.4 |
| | $V_{of}$ % | 5 | 0.28 | 1.11 | 0 |
| | | 8 | 0.4 | 1.25 | 0.5 |
| Current Magnitude | Trend | 5 | Decreasing | Decreasing | Flat |
| | | 8 | Increasing (Osc) | Decreasing (Osc) | Flat (Zero) |
| | Correlation (PCC) | 5 | Reference (1) | Correlated (0.87) | Correlated (0.4) |
| | | 8 | Reference (1) | Neg. Corr. (-0.66) | Neg. Corr. (-0.44) |
| | $I_{nf}$ % | 5 | 1.94 | 2.5 | 29.18 |
| | | 8 | 4.28 | 4.32 | - |
| | $I_{of}$ % | 5 | 0.13 | 0 | 11.87 |
| | | 8 | 0.14 | 0.11 | - |
| Frequency | Trend | 5 | Decreasing | Decreasing | Decreasing |
| | | 8 | Decreasing | Decreasing | Decreasing |
| | Correlation (PCC) | 5 | Reference (1) | Correlated (0.99) | Correlated (0.99) |
| | | 8 | Reference (1) | Correlated (0.97) | Weak Corr. (0.55) |
| | RoCoF (Hz/s) | 5 | -3.76 | -3.76 | -3.76 |
| | | 8 | -0.43 | -0.43 | -0.89 |
| Active Power | Trend | 5 | Flat (Osc) | Flat | Flat |
| | | 8 | Increasing (Osc) | Decreasing (Osc) | Flat (Zero) |
| | Oscillation frequency (Hz) | 5 | 3.21 | 3.21 | - |
| | | 8 | 1.87 | 1.87 | - |

Osc. (oscillation), Neg. Corr. (negative correlation).

- Post-processing ⇒ feature table is **in progress**.
- Summary report generation is presently **in progress**.

## Conclusion and Scope

1. Key steps in a post-mortem analysis are presented.
2. Initial pre-processing steps to derive inferences.
3. Free and open-source tools like Qt Designer and Python are used.
4. A few rudimentary features are extracted, which can be adapted further as per user requirements.
5. We expect that the analysis presented will be of **educational value for students and practicing engineers**.

Fig. 10: Github link for PPT and UI.

## References

[1] Silverstein, A., and J. Follum, "High-resolution, time-synchronized grid monitoring devices," *PNNL-29770. Richland, WA: Pacific Northwest National Laboratory.* [Available online] at NASPI Archive: https://www.naspi.org/node/819 (2020).

[2] P. Navalkar, A. M. Kulkarni, Santosh V. Singh, and S. A. Soman, "A proposal for a PMU based adaptive islanding scheme for Mumbai city," 22nd National Power Systems Conference (NPSC), IEEE, 2022.

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