Application of Synchronized Waveform Data to Power System & Apparatus Monitoring

Presented by

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Outline:

1. Status and characteristics of synchronized waveform (sync-wave) data

2. Three platforms of sync-wave applications

3. Strategies to develop sync-wave based applications

4. Synchrophasor versus sync-wave data - a brief comment

5. Conclusions & main takeaways

1. Status and characteristics of sync-wave data

Defining synchronized waveform (sync-wave) data – three characteristics:

- Voltage or current waveform data (sampled at least 64 samples/cycle, or 3.8kHz),
- With (explicit or implicit) precision time information for the data samples,
- The information is sufficient to align waveforms recorded at multiple locations to an acceptable accuracy (to be established by a standard).

Example of sync-wave data

Hour	Minute	Second	Loc 1 Volt
23	5	0.000001	-109.63
23	5	0.000066	-113.68
23	5	0.000132	-117.47
23	5	0.000197	-120.35
23	5	0.000262	-122.78
23	5	0.000327	-125.24
23	5	0.000392	-127.44
23	5	0.000457	-129.19
23	5	0.000522	-130.97

Hour	Minute	Second	Loc 2 Volt
23	5	0.000217	100.12
23	5	0.000282	103.45
23	5	0.000347	106.88
23	5	0.000412	109.44
23	5	0.000478	111.64
23	5	0.000543	113.62
23	5	0.000608	115.62
23	5	0.000673	117.50
23	5	0.000738	119.54

- 256 samples/cycle, i.e. 15.9kHz sampling rate
- 1μSecond GPS timestamp accuracy

You can get this and other data from the PES PQ Data Analytics WG website: https://grouper.ieee.org/groups/td/pq/data/

1. Status and characteristics of sync-wave data

Devices with sync-wave measurement capabilities (SMU) are already available

Portable PQ monitor

Stationary PQ monitor

Gapless SMU

Relay-based SMU

Merging Unit

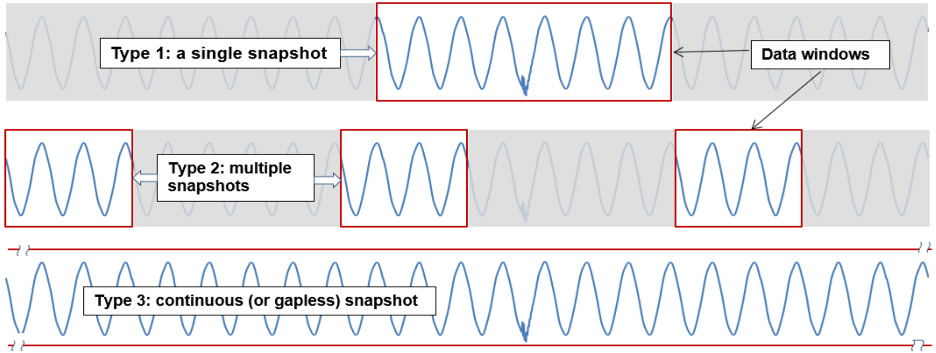
Three industry trends driving the need for waveform data:

- Increased adoption of power electronic (PE) apparatuses in power systems
- More complex system dynamics (e.g. inverter-caused SSR)
- The move to online apparatus condition monitoring

SMU – sync-wave measurement unit (a generic name to facilitate description here)

1. Status and characteristics of sync-wave data

- **Types of data**
- **Forms of data**
  (for eventual synchronized analysis)
  - Raw waveform data
  - Derived data (i.e. indices)
- **Scheme of data collection and transfer**
  - On-demand such as download
  - Event driven
  - Real-time streaming
- **Central location for synchronized analysis**
  - It does not mean control center only
  - It can be a substation or even an engineering office



Differentiate
three concepts about the data:

- data with precision time information,
- synchronized recording of data,
- synchronous transfer of (real-time) data.

1. Status and characteristics of sync-wave data

Classification of applications:

1) Offline analysis

2) Online monitoring
(no automatic action)

3) Real-time P&C
(protection & control)

How sync-wave data is used is highly dependent on the type of applications. Real-time streaming of the data to control center is only one of the possible approaches

Table I: Characteristics of sync-wave data as affected by applications.

Data Characteristics \ Application types		Offline Analysis	Online Monitoring	Real-time P&C
Data Type	1: Single snapshot		3	4
	2: Multi-snapshot			
	3: Gapless snapshot	2		1
Data Form	Time-domain			1
	Derived form	2	3	4
SMU Type	Stationary		3	1,4
	Portable	2		
Trans-mission Scheme	A: Download	2		
	B: Event-driven		3	4
	C: Streaming			1
Trans. Mode	Real-time			1,4
	Delayed	2	3	
Central location	Control center		3	4
	Substation			1
	Engineering office	2		

2. Three platforms of sync-wave applications

Platform No.1: Special purpose sync-wave platforms

- For (real-time) protection & control applications
- Extremely high reliability requirement due to automatic control actions
- Customized, dedicated SMU network is the most acceptable approach
- Consistent with current industry practice

Platform No.2: Multi-Use Sync-wave Platforms

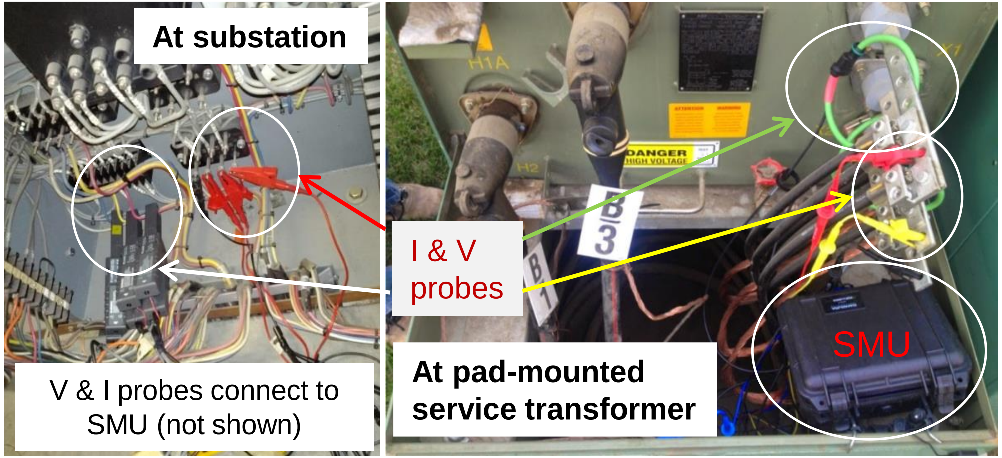
- For online monitoring and offline analysis applications
- Real-time streaming of data is NOT necessary
- Thus a lot more options are available to construct such a network

2. Three platforms of sync-wave applications

Platform No.3: Mobile Sync-wave Platforms Using Portable SMUs

- For offline analysis, e.g. troubleshooting, model validation, forensic analysis etc.
- Can be deployed at almost any locations with little infrastructure support
- A very important tool to support university research including emulating PMUs

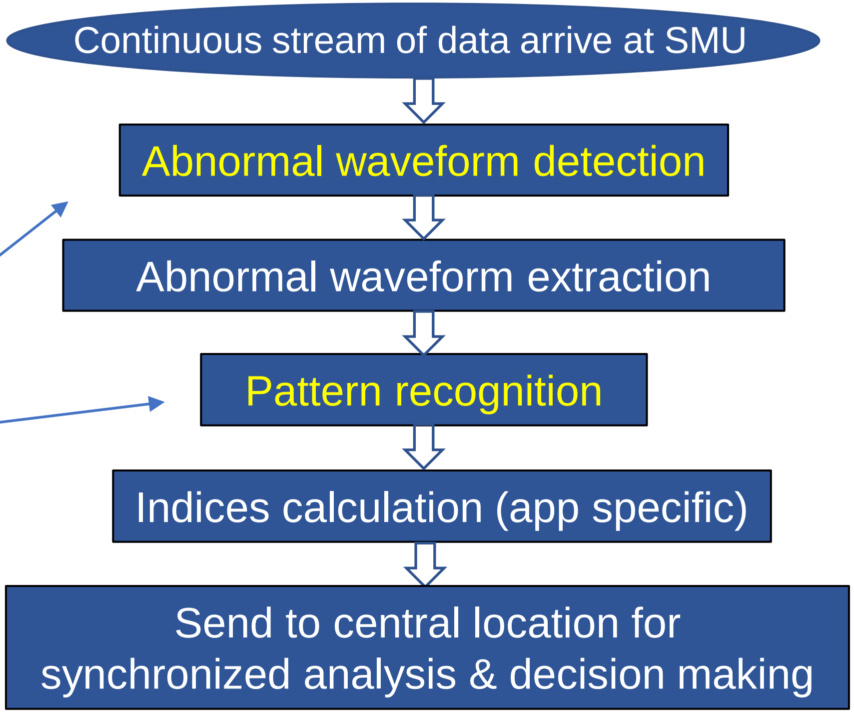
Installation of two SMUs (Portable PQ monitors) of example 2



2. Three platforms of sync-wave applications

Need to research and develop general-purpose data analytics algorithms

- Most useful sync-waves are those that contain changes or disturbances (called abnormal waveforms here)
- Focusing on abnormal data reduce capacity requirements on infrastructures
- Need to develop general-purpose abnormality detection & pattern recognition algorithms
- It is also useful to research application specific data analytics algorithms (such as extracting SSR indices)



SMU seems to be the best location to perform the above analysis

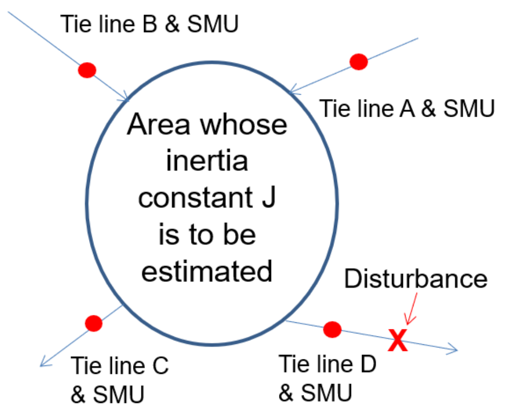
3. Strategies to develop sync-wave based applications

Unique strengths of sync-wave data

- Waveform data is not new to power system engineers
- What is new is that waveform data from multiple locations can now be analyzed together due to their being able to time-aligned properly

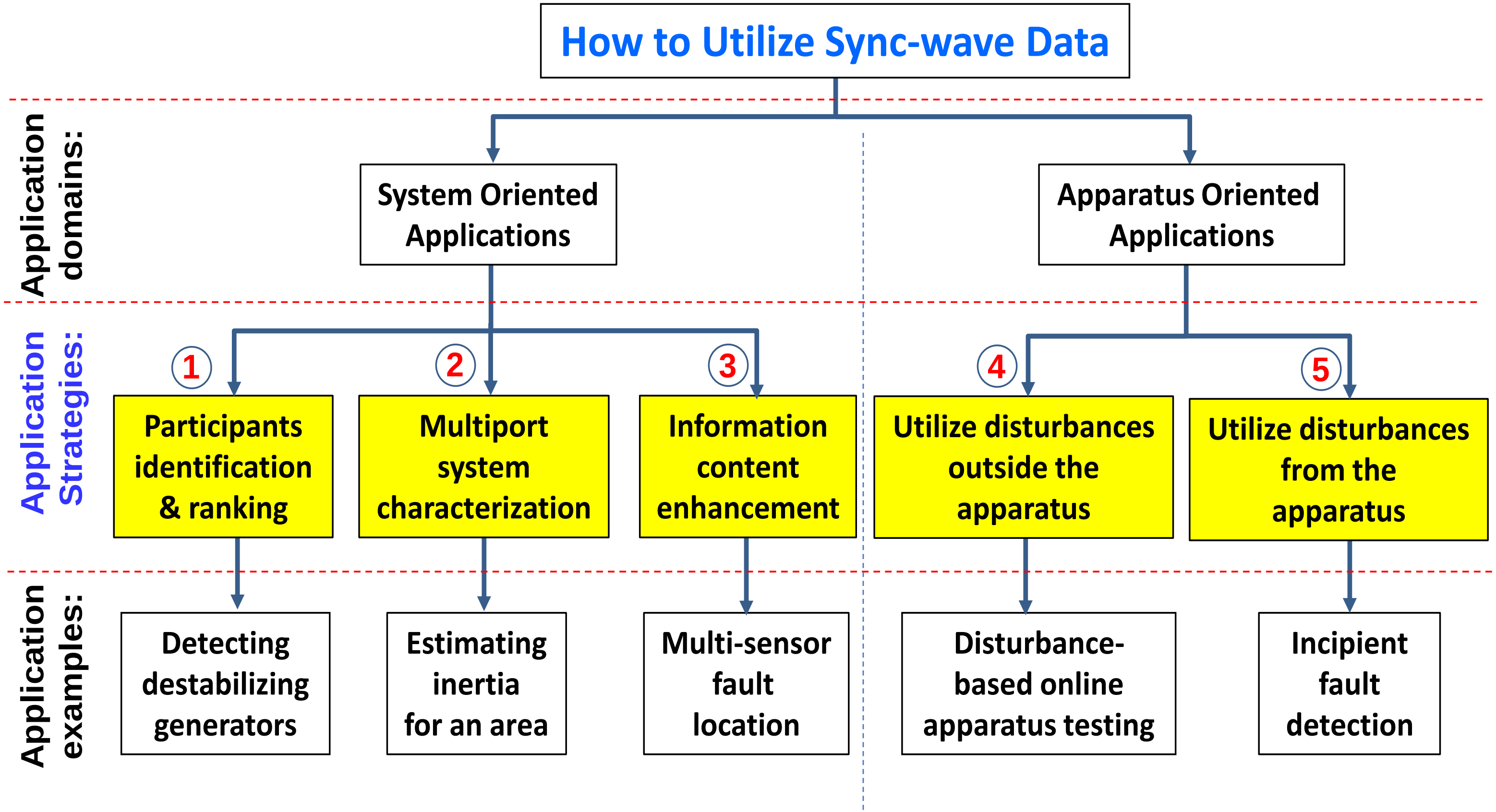
Values of multi-location data:

- Help to solve location related problems, e.g. which inverter triggers instability?
- Support multi-port network/component characterization: e.g. inertia of a regional power system
- Enhance information using multiple data: e.g. differential protection and fault location



An example multiport problem

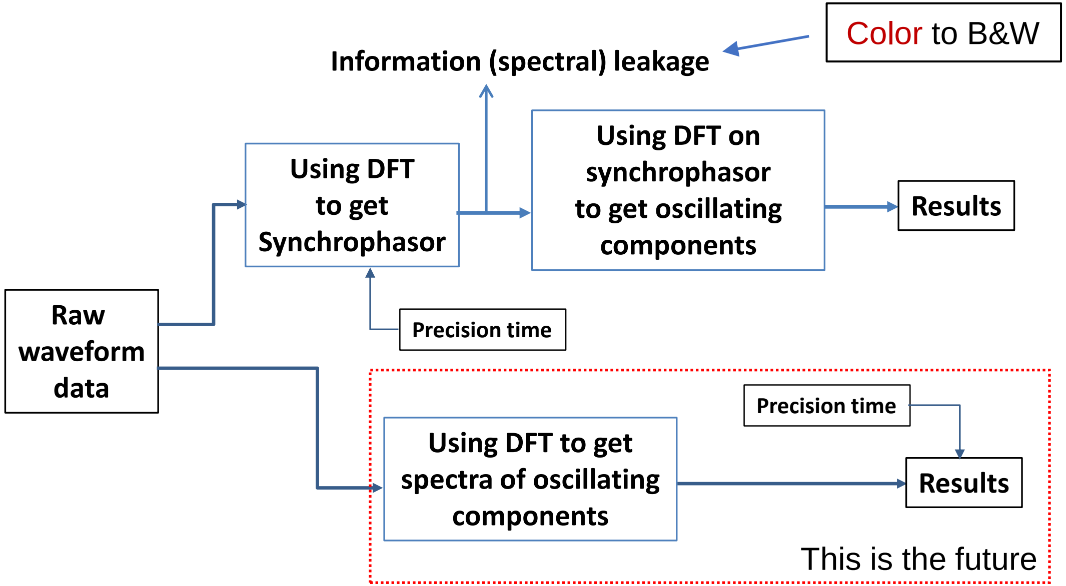
3. Strategies to develop sync-wave based applications



See the paper for details

4. A brief comment - Sync-wave versus Synchrophasor

- Synchrophasors are calculated from waveforms, i.e. a derived form of sync-wave
- Information is lost when transforming waveform data into a single index
- Anomaly in a waveform cannot be captured by phasors
- Since many applications don't require real-time streaming of waveform data, the main advantage of phasor – less demand on communication – does not really exist



Why tie up our hands with a processed data?

Why limit our imagination to one complex number?

We deserve more!

• 6. Conclusions & Main takeaways

- Waveforms are the most authentic and granular data revealing power system behaviors. They provide much more information than the phasor data

- The main strength of sync-wave is to enable integrated analysis of multi-location data, thus sync-wave is especially useful for solving problems involving:

    - Interactions of multiple components (e.g. ranking, contributor identification)
    - Multiport systems or subsystems (e.g. characterizing an area instead of a component)
    - Cross-referenced information extraction (e.g. differential analysis)

- Real-time streaming of sync-wave data is not necessary for many applications. It is needed mainly for a dedicated platform serving a specific control function

- Two other platforms, multi-use (on-demand access) platform and mobile platform are likely to be more useful, at least at the early stage of sync-wave adoption

- Sync-wave data can support both system and apparatus oriented applications

I welcome any questions and comments

A more detailed presentation including recording can be found from

https://www.naspi.org/node/931

NASPI: North American SynchroPhasor Initiative