Framework for synchrophasor measurements data processing and the case studies of the low-frequency oscillations

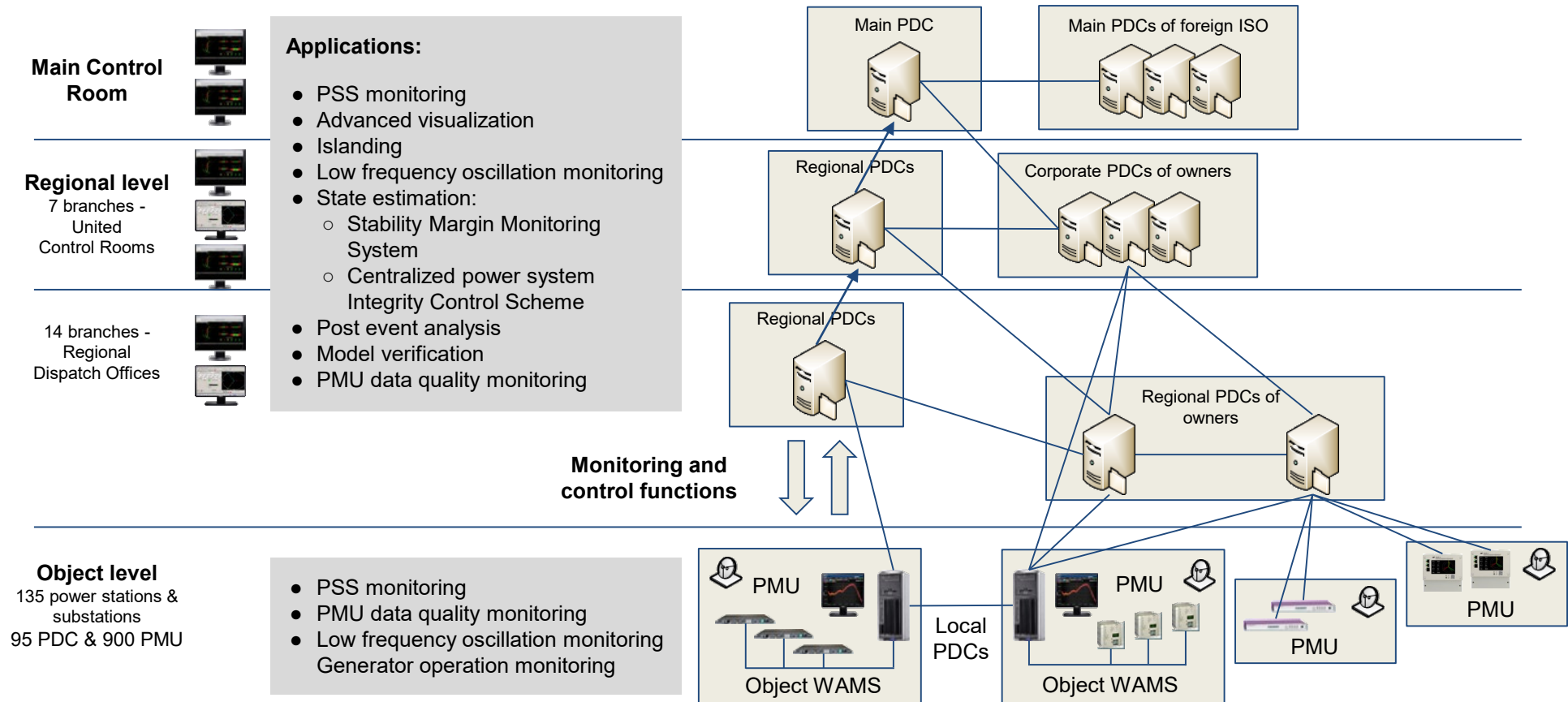A. Popov[1,2], K. Butin[1,2], D. Dubinin[3], A. Rodionov[1]

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[2]Northern (Arctic) Federal University, Russia
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«SO UPS», JSC   ens   cacby

WAMS development in Russia

Main Control Room

Regional level
7 branches -
United
Control Rooms

14 branches -
Regional
Dispatch Offices

Object level
135 power stations &
substations
95 PDC & 900 PMU

Applications:

- PSS monitoring
- Advanced visualization
- Islanding
- Low frequency oscillation monitoring
- State estimation:
  - Stability Margin Monitoring System
  - Centralized power system Integrity Control Scheme
- Post event analysis
- Model verification
- PMU data quality monitoring

- PSS monitoring
- PMU data quality monitoring
- Low frequency oscillation monitoring
  Generator operation monitoring

Main PDC

Main PDCs of foreign ISO

Regional PDCs

Corporate PDCs of owners

Regional PDCs

Regional PDCs of owners

Monitoring and control functions

PMU

PMU

PMU

PMU
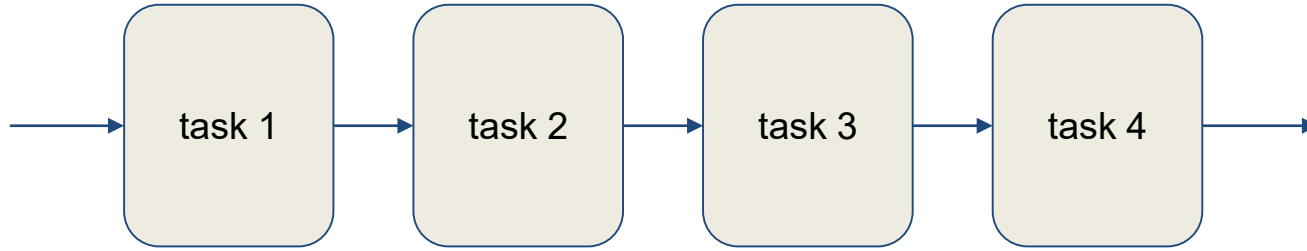
Local PDCs

Object WAMS

Object WAMS

Low-frequency oscillations

- The experience shows that LFO occur more than **10 times a day** in the power system of Russia

- **Continuous online monitoring** of LFO and their **source detecting** in the dispatch center is required

- Challenges:
  - **low observability** of the power system
  - the source can be located in **neighboring countries**

Review 2015 – 2020

- **Focus of attention:** physics of oscillatory processes in big systems, detecting and identifying the low-frequency modes, developing new methods for locating the source of oscillations, real-time processing the large amounts of data, computational infrastructure.

- **Sequence of common subtasks:** data preprocessing, mode detection and selection, calculation the parameters of modes, source detection.
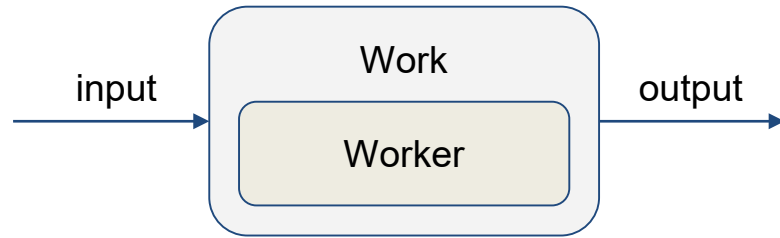
Set of solutions

$$N = n_1 \times n_2 \times n_3 \times n_4$$

- Methods
- Parameters
- Implementations

Plan

- worker is activity
- plan may be worker

```
{
    "class"    :    "WorkNode" ,
    "id"    :    "freq"    ,
    "inputs"    : [    "get_mode" ],

    "work"    : {
        "descr"    :    "Get frequency of mode"    ,
        "worker"    : {
            "class"    :    "modulation.IqFreq"    ,
            "params"   : {...}
        }
    },

    "result"    : {
        "indep"    :    "Time"    ,
        "dep"    :    "Frequency [Hz]"
    }
}
```
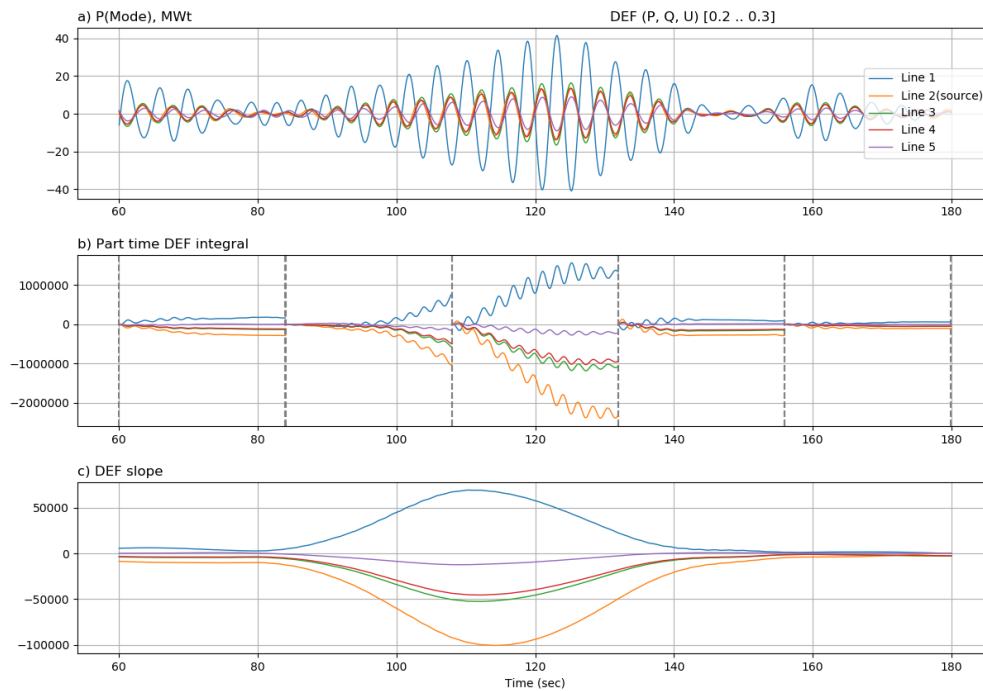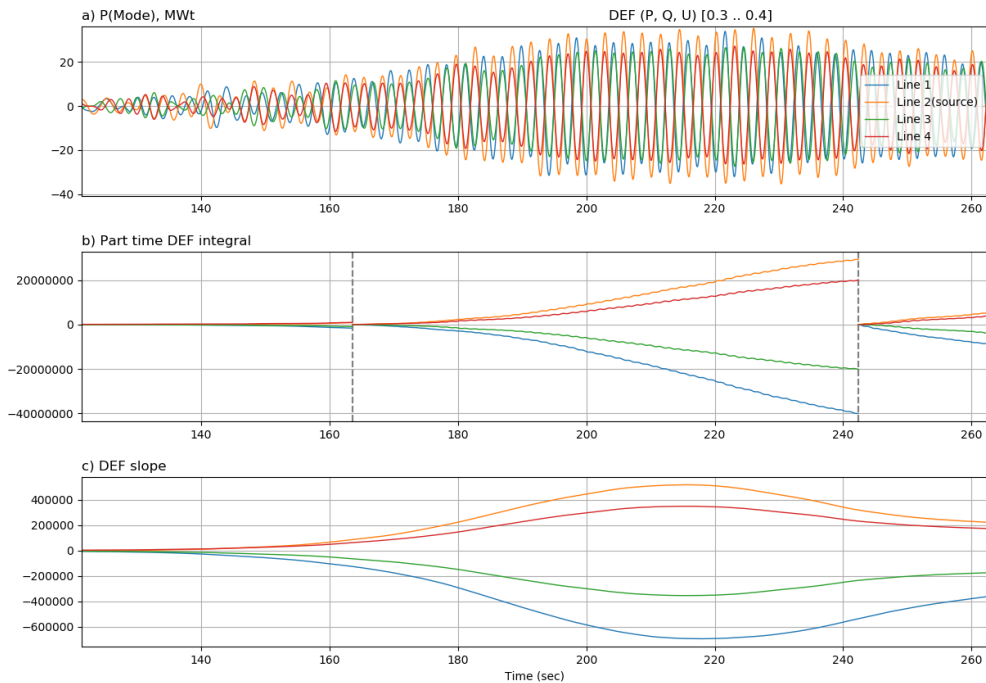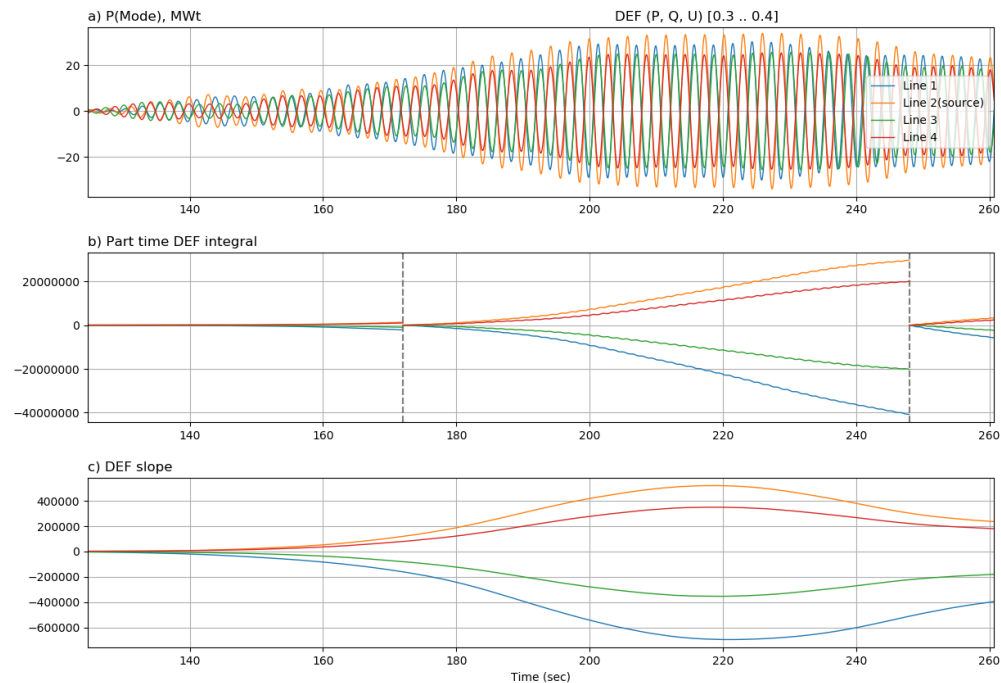
Varying the worker: get mode

FIR-filter (401 taps)

IIR-filter (Butterworth, 3 order, 14 taps)

Varying the worker: get mode
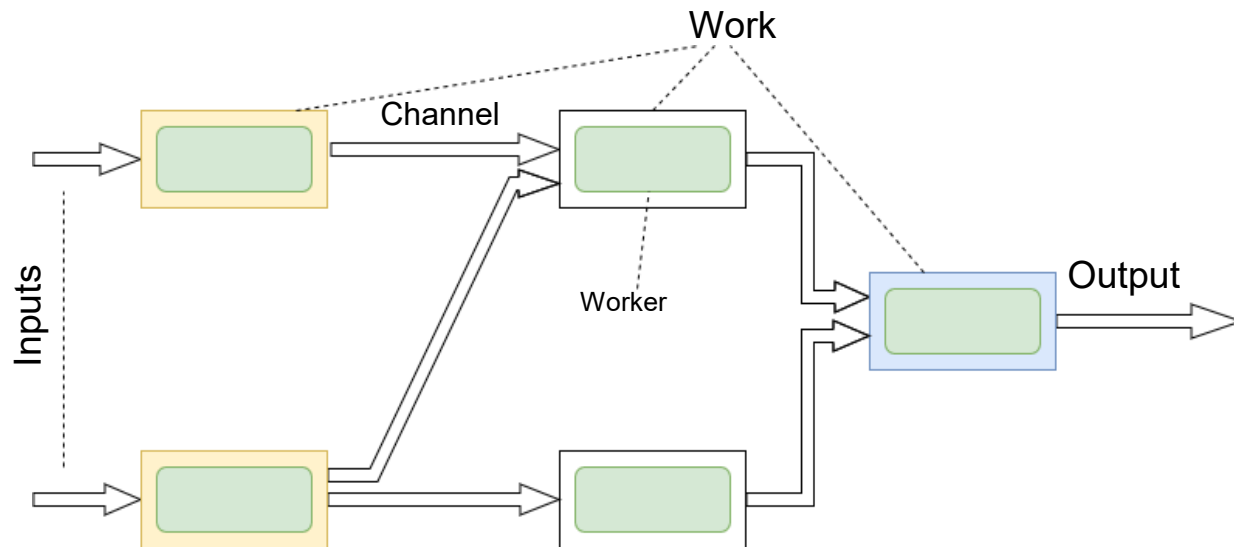

FIR-filter (301 taps)   IIR-filter (Butterworth, 3 order, 14 taps)

Dsplab

- Field of application: Development of the DSP routines that require a flexible configuration of different stages of calculations on the user level; **investigation of variety of methods** solving the same DSP task.

- User can define the **plan of works** and then set the workers. The replacement of the worker does not destroy the workflow.

- Types of nodes: **Work**, **Map** (**Loop**), **Select** and **Pack**

- Licence: **LGPLv3**

- Programming language: **Python 3**

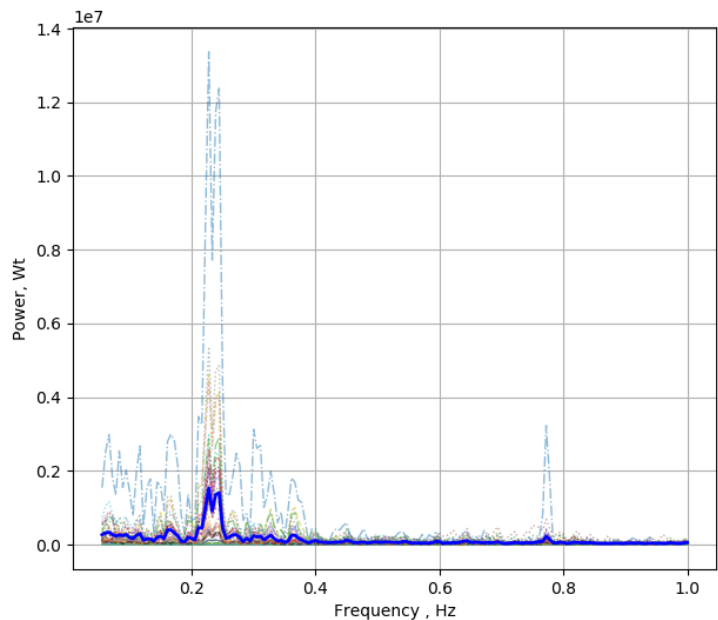github.com/aleneus/dsplab

Parallel implementation

- There are different strategies for **splitting data** for parallel processing
- But the **functional nature of the plan** itself provides the automatic parallelism
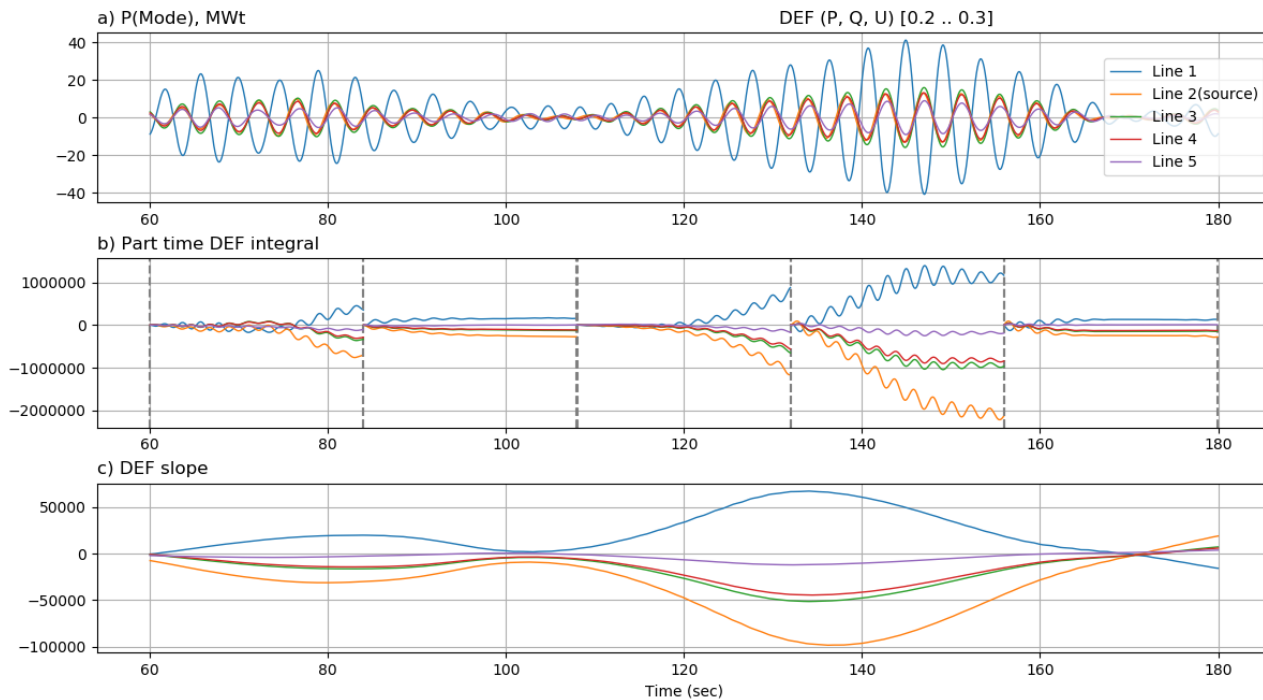- Suitable software development technologies: **"lightweight" threads**, **channels**

Real LFO cases

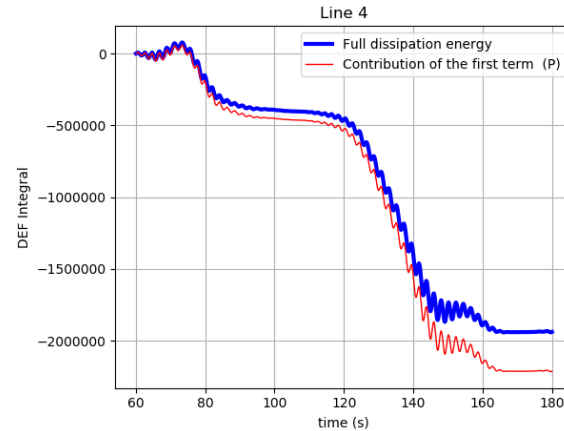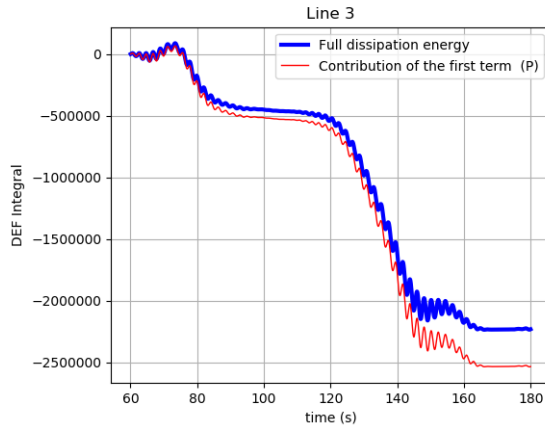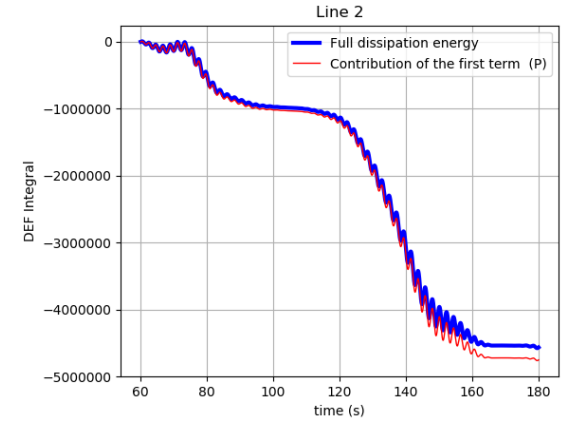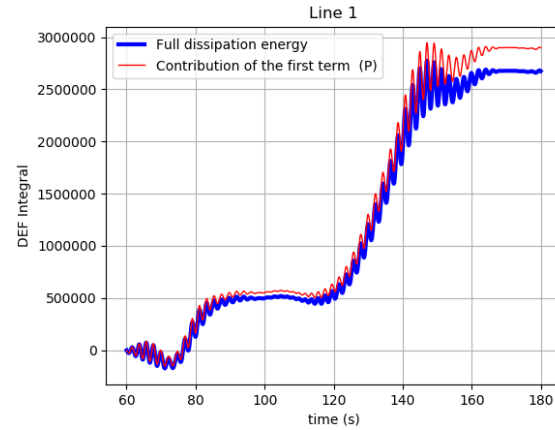| #	Date	Region	Number of data sources	Dataset	Record duration (min)	Mode (Hz)	Amplitude (P, MW), max	Duration of oscillations (min)
1	29.05.2018	North-central	83	f	5	0.5 - 0.7	–	1
2	07.03.2019	West	5	f, P, Q, U	4	0.7	12	3
3	02.05.2020	Central	114	P	2	0.13, 0.3	12	2
4	04.05.2020	Central	114	P	3	0.31	18	2
5	04.05.2020	Central	114	P	2	0.25 - 0.3	20	1
6	16.06.2020	West	116	f, P, Q, U	4	0.25 - 0.3, 0.11	22	1
7	02.09.2020	South	47	f, P, Q, U, I	3	0.25	40	2
8	24.09.2020	South	67	P, Q, U	5	0.2 - 0.3	55	0,5
9	25.11.2020	Syberia	202	f, P, Q, U	15	0.35	30	10

Case #7

a) Amplitude power spectrum
Energy Flow method

b) Dissipation

P and Q contribution

$$DEF_{ij}(t) = \int \left(\Delta P_{ij} d\Theta_i + \Delta Q_{ij} \frac{dV_i}{V^*_i} \right)$$

Conclusion

- Detection the source of LFO is one of the **many stages** of processing the synchrophasor measurements data.

- Due to the **growing variety of methods** for solving individual subtasks, program tools, allowing us to **explore** combinations of methods and **apply** the most successful ones are in demand.

- An approach to the representation of the data processing in the form of a generalized scheme (**plan**) with the possibility of variation of the used stage implementations is proposed.

- In the context of a generalized processing scheme, the **DEF method** has been successfully applied to analyze several real LFO cases in the power system of Russia.

Thank you for your attention!

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