Experiences in synchrophasor applications in Russia

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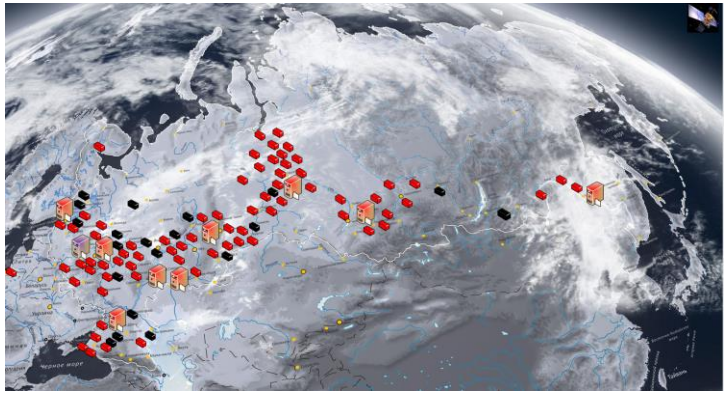
Panel 9. WAMS development in Russia

- **Start of creation of WAMS in Russia – 2005**
- **Basic conception is focus on the development and implementation of national solutions and PMU&PDC**
- **Basic goal of synchrophasor technology development is improvement of operational and automatic control technologies of power system:**
  - New quality information about the behaviour of power system;
  - The creation of WAMS in Russian power system (on-, off line);
  - The development technological tasks/systems based on PMU data (WAMPAC);
  - The deployment of WAMPAC into the dispatch loop.

	Problem	Decision
1	Development of national standards	❑ PMU & PDC requirements ❑ development a set of tests of PMU & PDC ❑ WAMS requirements (development, deployment, operation)
2	Requirements to equipment of PMU on power stations (P ≥ 500 MW), substations (U ≥ 500 кV) in: ❑ transmission lines (U ≥ 330 kV); ❑ generators (more than 200 MW), hydrogenators (more than 100 MW); ❑ lines & transformers in control sections U ≥ 220 kV	
3	Implementation of national solutions	Five producers of PMU & PDC and software
4	PMU & PDC certification	The creation of PMU & PDC certification system



- **1** main PDC, **21** regional PDC (2022 – more than **26**)
- **135** WAMS stations/substations (2022 – more than **150**)
- **900** PMU (2022 r. - more than **1000**)

The level of development of synchrophasor technology in Russia is sufficient to improve the technology of monitoring and control of power system operation based on PMU data

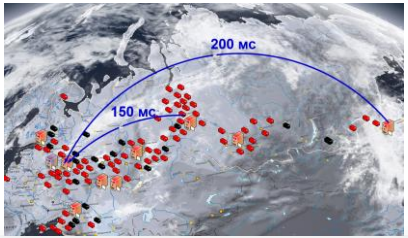
Panel 9. PMU data communication system creation

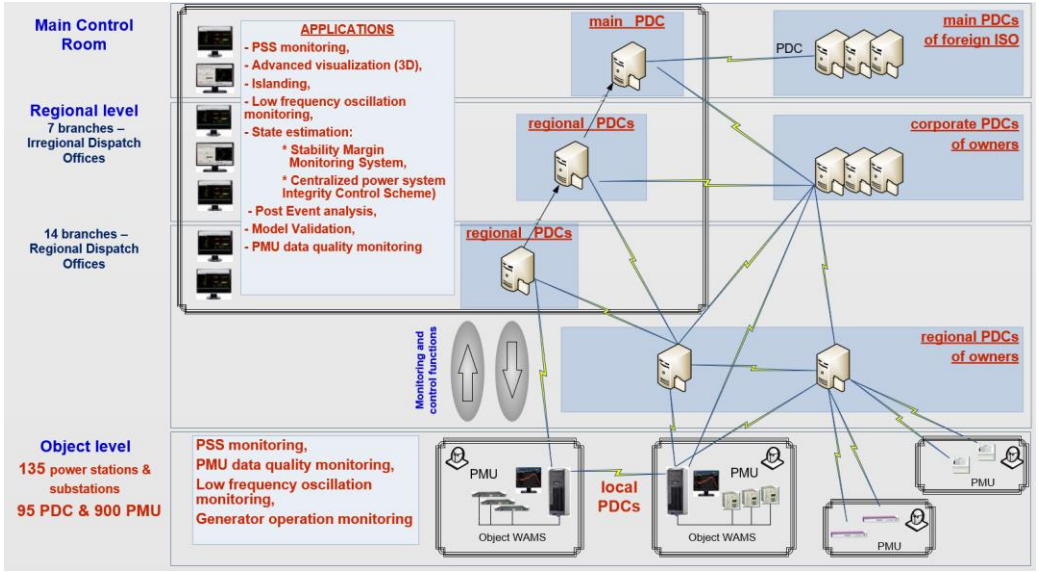
Technical improvement of WAMPAC based on PMU data critically depends on communication system and PMU data quality:

- ❑ set of PMU performance requirements;
- ❑ characteristics of PMU data communication system.

Requirements to PMU data quality is defined by functionality of WAMPAC and the decision time requirements

Problem	incorrect operation of WAMPAC by reducing PMU data quality
Decision	automatic monitoring of PMU data quality in all communication system nodes to prevent incorrect operation of real time control system





Characteristics of communication system:

- ❑ latency in online – 50 .. 200 ms
- ❑ PMU data losses – less of 0,1%

In Russia created the PMU data communication system that enables to use PMU data for real time control systems of power system

Panel 9. Synchrophasor applications in Russia

System for Monitoring the Operation of System Regulators

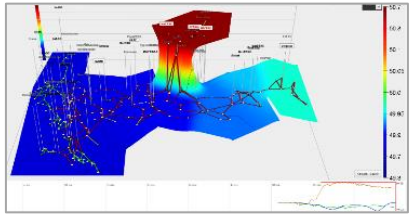
The main function - real-time identifying of typical faults in the generator excitation systems and PSS based on PMU data

Prospects: deployment in 50 power stations

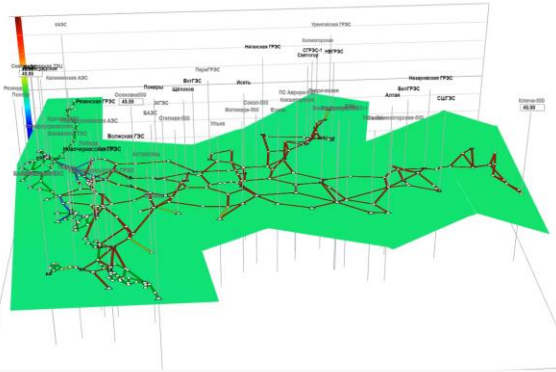
3D-visualization online monitoring system

- ❑ real-time visualization of frequency and voltage level;
- ❑ identification of type of disturbances;
  - ❑ low-frequency oscillation monitoring;
  - ❑ islanding monitoring;
- ❑ post-mortem analysis;
- ❑ dispatch staff training

Prospects: integration of expert functions.



islanding monitoring



Disconnection of 3,5 GW generators

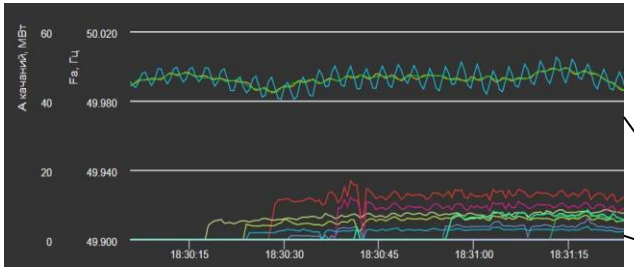
oscillations

Panel 9. Synchrophasor applications in Russia

Low frequency oscillation online monitoring

- low frequency oscillation monitoring in control sections of power system:
  - amplitude of active power oscillations;
  - duration of oscillations;
  - oscillation source identification;
- generating an alarm when the preset settings are exceeded.

! practical experience: there were recorded more than 10 cases of long-term high-amplitude oscillations in the power system of Russia in 2011-2020, which led to the shutdown of generating equipment / islanding



oscillations

amplitude of oscillations in control sections (MW)

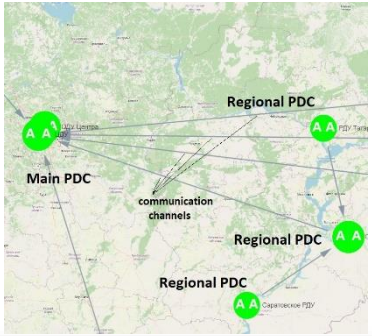
PSS monitoring (online)

State estimation (using results of SE in Stability Margin Monitoring System)

PMU data quality monitoring + life cycle PMU&PDC monitoring

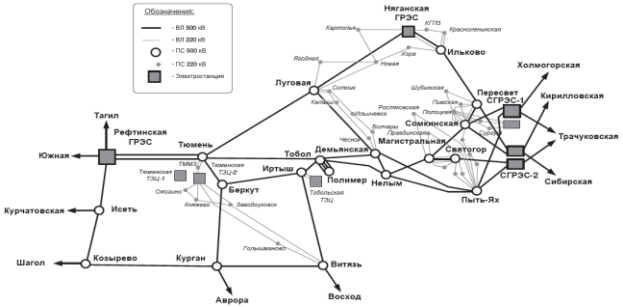
- identification of «weak link» in communication system (every minute)
- real-time identification of PMU data quality:
  - latency of data & data losses;
  - verification of measurements;
  - monitoring the characteristics of data flows in all nodes of the communication system

Class	Latency (ms)	Losses (%)
class A	100	0,2
class B	100..500	0,2
class C	500..1000	0,2 .. 2
class D	1000..2000	2,0 .. 10
class E	> 2000	> 10
class F	the data is not correct	

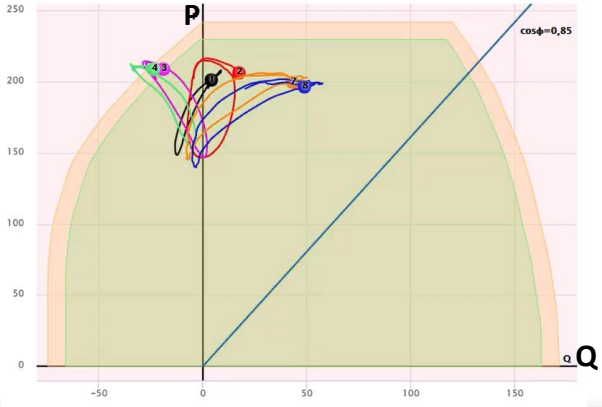


Panel 9. Prospects of synchrophasor technology development

- Advanced PMU development:
  - increase sampling (to 1000 Hz) and reporting (to 200 Hz),
  - increasing accuracy in electromechanical transients,
  - improve performance (decreasing of time response)
- Deployment of Wide Area Control Systems
- Dispatch adviser development
- Dynamic model validation
- Development of advanced software based on neural networks and big data analytics
- Development of software based on PMU data for power station & substation tasks:
  - health of station & substation equipment monitoring;
  - early alarm for potential malfunctioning equipment;
  - Potential Transformers monitoring;
  - statistical analysis of generator operating modes
- Deployment of new procedures and practices:
  - PMU & PDC calibration and certification,
  - testing of interoperability of PMU & PDC & software,
  - end-to-end testing



WACS based on angle



oscillations between generators on P-Q diagram