CIGRE UK Webinar Series 2017:
Wide Area Protection & Control Technologies

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Presentation Outline

1. Introduction and WAMPAC Overview
2. Key Conclusions
3. TB 664 Chapters Review
1. Introduction and WAMPAC Overview
Key Objectives

1. Review of Synchronised Measurement Technologies

2. Understanding of Benefits of Synchrophasors to the Protection and Control of Power Systems

3. Review and Discussion about the Existing Practical WAMPAC Applications Worldwide

4. Identification of Challenges and Requirements of WAMPAC

5. Conclusions

6. Bibliography

(To exclude from the assessment aspects related to Wide Area Monitoring)
Introduction and WAMPAC Definition

Wide Area Monitoring, Protection and Control (WAMPAC) is the emerging practice of using wide area, synchronised measurements as the basis for improving understanding of the power system through *real time monitoring and visualisation*, enhancing existing operating practices by integrating improved measurement technologies, and creating entirely *new real time control and protection practices*.

The need for new protection and control approaches is emerging in power systems world-wide, as they become more complex (renewable energy integration, energy efficiency, electrical vehicles, storage, etc.) and are being operated closer to their physical limits in an attempt to satisfy the conflicting economic, environmental and security demands placed upon them.
Introduction and WAMPAC Definition

Key technological enablers of WAMPAC are:

1. New sensors (Synchronized Measurement Units, i.e. Phasor Measurement Units)
2. Communication infrastructure (high-speed, reliable, cyber secure)
3. Last generation of fast computers

**Situation today:** technology is available, there is a need for new applications and more secure communication infrastructure for supporting wide area control and protection
Introduction and WAMPAC Definition

WAMPAC fundamentals available in e.g. the following publication:

Introduction and WAMPAC Definition

Generic architecture of WAMPAC system
Introduction and WAMPAC Definition

Wide Area Monitoring Systems (WAMS) are enabling:

1. Situational Awareness
2. Open-Loop Control
3. Decision Support

Eventual problems with Communication Infrastructure would not lead to significant power system problems.

This is NOT the case when it comes to Wide Area Control (WAC) and Wide Area Protection (WAP).

We are moving towards integrated WAMPAC systems
2. Key Conclusions
WAMPAC Benefits

Four major categories:

**Data Analysis and Visualization** – Significant benefits have already been achieved using the systems that are already deployed.

**System Availability Enhancement and Blackout Prevention** to improve System Reliability, including real-time control and protection – The benefits of preventing a blackout are difficult to quantify due to a number of factors involved, such as damage to the economy, loss of confidence in the power system and the potential for serious accidents or even deaths,

**System Operation and Planning**, including modelling and restoration – Enables a paradigm shift toward the real time tracking of grid dynamics and system measurements and away from estimation,

**Market Operations and Congestion Management** - significant potential financial benefit by enabling the utilisation of accurate and optimal margins for power transfer (instead of the worst case scenario used under current practices).
WAMPAC Architecture

Needs to address the following issues:

**Scalability:** As the number of installed PMUs and IEDs with integrated PMU functions will increase over time, the system architecture must be designed so that it can accommodate this increase.

**Flexibility and Life Cycle Asset Management:** As many of the system components will be acquired, installed, operated and maintained by different entities, the system architecture must be flexible enough to accommodate the diverse requirements of various entities.

**Communications bandwidth and latency:** In the new paradigm, on-going communication costs may be the main cost item. Reducing the bandwidth requirement will help to reduce the on-going costs and help reduce the data latency.
Large-scale Deployment of PMUs

The following **process** is proposed to the industry to speed up deployment and minimize costs:

**Roadmap Development** - Each user in the grid should develop a near-, mid-, and long-term application/technology deployment roadmap

**Overall Infrastructure Architecture** – TNOs should foster data exchange and the development of the overall system infrastructure and common models. All users connecting to the overall architecture would need to satisfy key integration requirements

**Network Protocols, Software and Firmware Upgrades**, and **Data Access Security** - The consistent and accurate performance of all PMUs is key to the overall performance of the system.

**Regulatory Considerations** - Regulators at the government level need to provide incentives for technology deployment considering the potential of WAMPAC to deliver significant benefits for tax-payers and transmission system reliability.

**Company Process** - Each user should set up operational and business processes for installations, operations, maintenance, and benefits sharing.

**Research and Development** - Continue investing in Research and Development and promote the development and sharing of test cases to aid in the creation of new applications.
3. TB 664 Chapters Review
Chapter 1: Introduction to SMT

Synchronized Measurement Technology (SMT)

Aspects addressed:

1. Synchronized Measurement Units
2. Phasor Data Concentrators (PDCs)
3. Time Stamping using GPS or other timing sources
4. Synchrophasor Data and Flow
5. Time Synchronization Requirements, Filtering and Interoperability
6. Communication interface
Chapter 2: Benefits of Synchrophasors

Benefits to the Protection and Control of Power Systems

Enhancements that WAMPAC could offer in the areas of:

1. System Integrity Protection Schemes (SIPS),
2. Main and backup protection
3. Power system control functions:
   • Oscillatory Stability Monitoring
   • Wide-area Voltage Stability Monitoring, Instability Detection and Control
   • Applications for Inter-area Oscillations monitoring/control
   • WAMPAC for Frequency Stability
   • System (disturbance) recording and Analysis using PMUs
Chapter 3: Practical WAMPAC Apps

Practical WAMPAC applications worldwide

Aspects addressed:

1. Survey on usage and acceptance of WAMPAC in utilities worldwide
2. Summary of Survey Results
3. Existing Installations of PMU-based Wide Area Protection Schemes
Chapter 4: Challenges and Requirements

Challenges and Requirements of WAMPAC

Aspects addressed:

1. Design Consideration
2. Testing
3. Maintenance
4. Synchrophasor Standards and Guides
Three essential components: a) a time synchronizing signal (e.g. from GPS, or similar, receiver or from a local clock), b) a data acquisition module (anti-aliasing filter and A/D converter), and c) a communication module (communication processor).
Ch-1: Phasor Data Concentrator

The core component of any WAMPAC System

Tasks (overview):

1. Real-time data processing
   - time-alignment, down-sampling, interpolation
2. Support of defined standards and flexible connectivity to other PDCs
3. Protocol translation/conversion
4. Data storage
5. Detection and protection functions
   - Level/threshold detection;
   - Type of violation (under value, over value, rate-of-change);
   - Angle difference; Voltage instability;
   - Low-frequency oscillation detections; Frequency instability;
   - System Integrity Protection Schemes (SIPS).
6. System administration
Ch-1: Time Stamping

Correct PMU operation requires a common and accurate timing reference capable of determining the instant at which the voltage and current samples are acquired.

The accuracy of the timing signal should allow the PMUs to maintain synchronism whilst keeping the Total Vector Error (TVE) (i.e. the magnitude of the vector difference between the theoretical phasor and its estimate computed by the PMU) within the limits defined in IEEE Std C37.118-2011

Synchronizing Sources:

1. GPS (USA)
2. GLONASS (Russia)
3. Gallileo (Europe)
4. China…
5. Other timing sources…
Ch-1: Accuracy Requirements

IEEE Std C37.118.1-2011 includes the following information:

- Performance class ($p$ and $m$ classes)
- Measurements that meet this class of performance
- Test results demonstrating performance
- Equipment settings that were used in testing

Interoperability of PMUs and other WAMPAC components, such as Phasor Data Concentrators (PDCs).

Communication interface (LAN, Regional comms, WAN)
Ch-2 Benefits: SIPS (1/2)

This chapter describes:

1. Introduction to SIPS
2. SIPS architecture
3. Practical examples of opportunities for PMU enabled Wide Area Protection
4. SIPS based on synchronized measurement technologies

Representative examples, including underfrequency, or undervoltage load shedding, voltage instabilities mitigation, etc. are given.
Ch-2 Benefits: SIPS (2/2)

General framework for wide-area voltage stability monitoring, instability detection and control.

Also:

Dynamic Voltage Security Assessment
Ch-2 Improved Damping Performance

An example:
Ch-2 Improved Damping Performance

An example:

Generator power

Without PMU feedback

With PMU feedback

60 sec

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Cigre St Petersburg, Russia, 25/4/2017:
Wide Area Protection & Control Technologies
Ch-2 Improved Fault Location

Given a fault on overhead line, determine its location as accurately as possible
Ch-3: Practical WAMPAC - Survey

Four parts:

1. Interest in WAMPAC technologies
2. Drivers for WAMPAC technologies
3. Challenges and barriers to the introduction of WAMPAC technologies
4. Existing experience with WAMPAC technologies

42 responses from 23 countries
Ch-3: Practical WAMPAC - Survey

Level of interest in wide area technologies within company

- 44%: Very low, this is currently not a topic of interest in our company
- 29%: Very high, we currently have operational WAMPAC systems
- 15%: High, we have ongoing WAMPAC pilot or research projects
- 12%: Average, we are currently evaluating the technology
- 0%: Low, we are interested, learning about the technology but have not started any activities
Ch-3: Practical WAMPAC - Survey

Planned introduction of wide area technology

- 49% Already introduced
- 33% 0-5 years
- 10% 5-10 years
- 8% More than 10 years
Ch-3: Practical WAMPAC - Survey

Type of WAMPAC systems in operation

- None: 19.5%
- Pilot projects only: 22.0%
- Wide area monitoring: 51.2%
- Wide area control applications: 12.2%
- Wide area protection applications: 14.6%
Islanding detection scheme that uses wide-area measurements

Angle monitoring
Ch-3: Practical WAMPAC - Examples

China

- Normal
  - Rational power system structure
  - Effective preventive control

- Alert
  - The first-defence-line: High-speed relays

- Emergency
  - The second-defence-line: Stability control devices
  - The third-defence-line: Out-of-step relays, frequency and voltage emergency control devices

- In extremis
  - Power system black start

- Restorative
  - The first-defence-line: High-speed relays

- Collapse
Ch-3: Practical WAMPAC - Examples

South Korea

Adaptive <f protection
Chapter 4: Challenges and Requirements

Each WAMPAC system consists of the following components:

1. PMUs
2. Communication networks
3. Phasor Data Concentrators
4. Phasor Gateways
5. Data Storage
6. System and Data Management
7. Application Tools

Criticality of the communication infrastructure
Chapter 4: Challenges and Requirements

Testing

Figure 111: Generic setup for testing a PMU
Hardware in the Loop testing
(RTDS, Opal-RT...
QUESTIONS?