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Decision Support System for power grid using multiple PMUs

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The Team

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Overview

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- Building a high-performance framework to facilitate big data analytics in the power grid
- Taking the first step to analyze the correlations among the data collected from multiple PMUs in a wide area
- Detecting disturbances in the transmission grid based on various patterns of PMU measurements in a wide area
  - Considering the abnormalities, such as small disturbances, switching events, and topology changes, which are usually hard to capture by operators.
  - Helping the operators to identify the root causes, locate the disturbances, and take appropriate countermeasures.
- Detecting disturbances based on oscillation analysis and stability evaluation

Hitachi's Vision for Decision Making Support System

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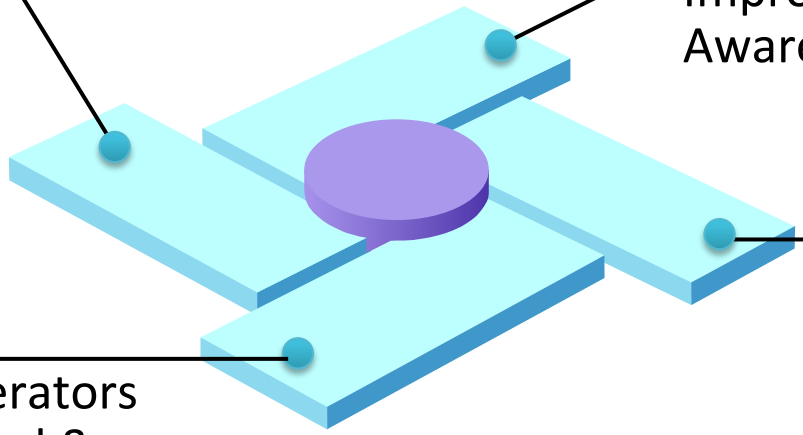
- Improving grid operator's "awareness"
- Supporting grid operators on "decision making" process
- Turning large-volume data into useful information



ACT
Secure Grid Reliability by proactive operation

OBSERVE
Improve Grid Operator's Awareness

DECIDE
Support Grid Operators making Economical & Efficient Decision

ORIENT
Data Mining and Statistics for Decision Making by Big Data Analysis

Big Data Analytics Platform for Power Grid

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- Handling various types of data sources
  - Structured data: PMU, SCADA, …
  - Unstructured data: documents, logs, …
- Extendable analytics platform
  - APIs for data management
  - Data analytics libraries
- Smart decision support
  - Offline analysis: learning event signatures
  - Real-time analysis: event detection & alarming
- High-speed data access
  - x100 fast Database Engine
  - High-speed data loading for huge data
  - Ad hoc data retrieval
- Wide-area Visualization

System Architecture

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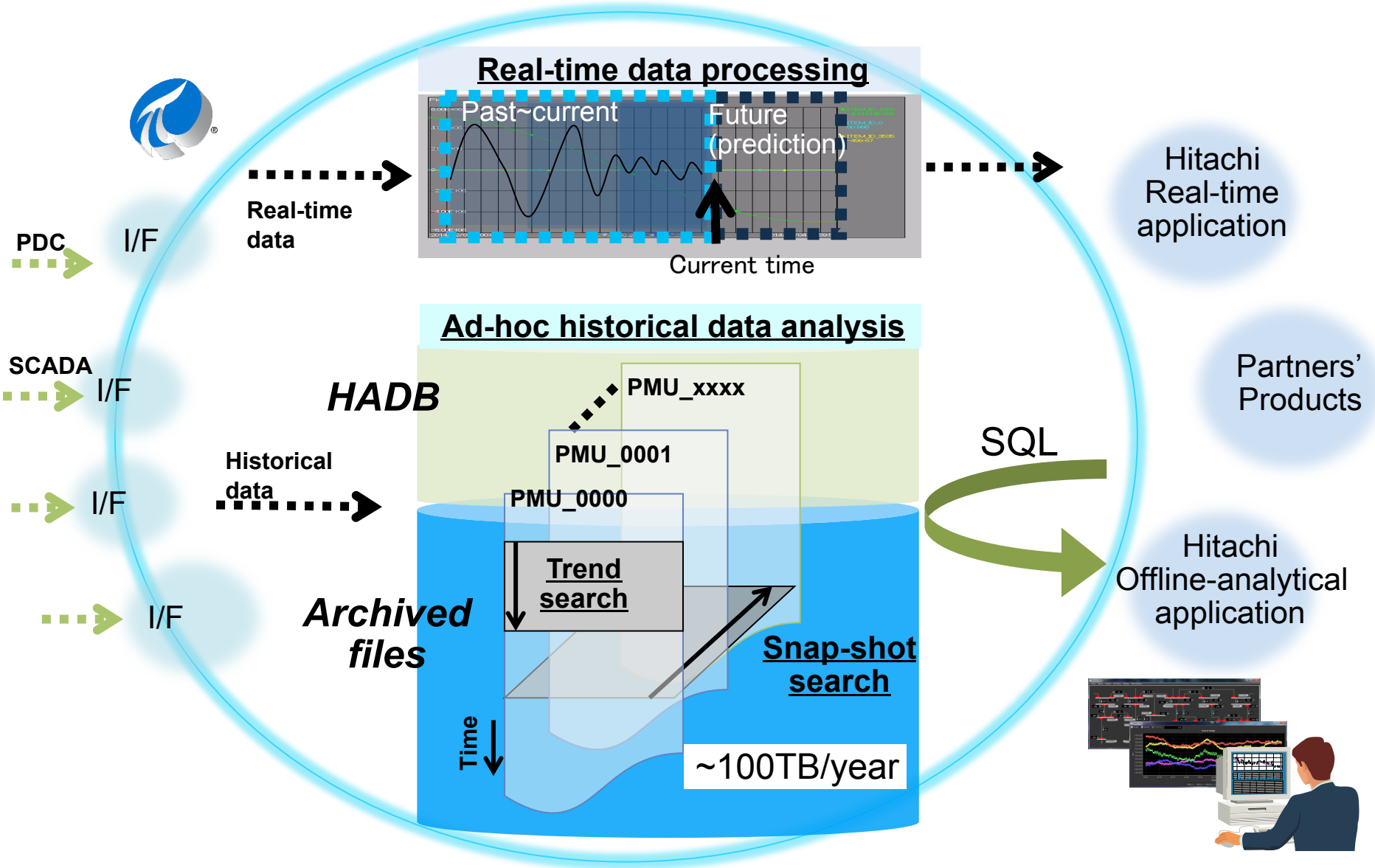

HADB: Hitachi Advanced DataBase

Event Detection

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- For each PMU and each data series (e.g., “relative phase angle”), features are computed from a sliding window of data:
  - Max FFT amplitude
  - Max residue from fitted complex exponentials
  - Max spectral density
  - Max change
  - …
- We use: 10s window length, computed every 1s
  - Depends on computational load: #PMUs, complexity of features
  - Easily distributed!
- Event screening
  - Multiple features: FFT, spectral density, min-max …
  - Adaptive detection threshold

Case Study (1) – regional event

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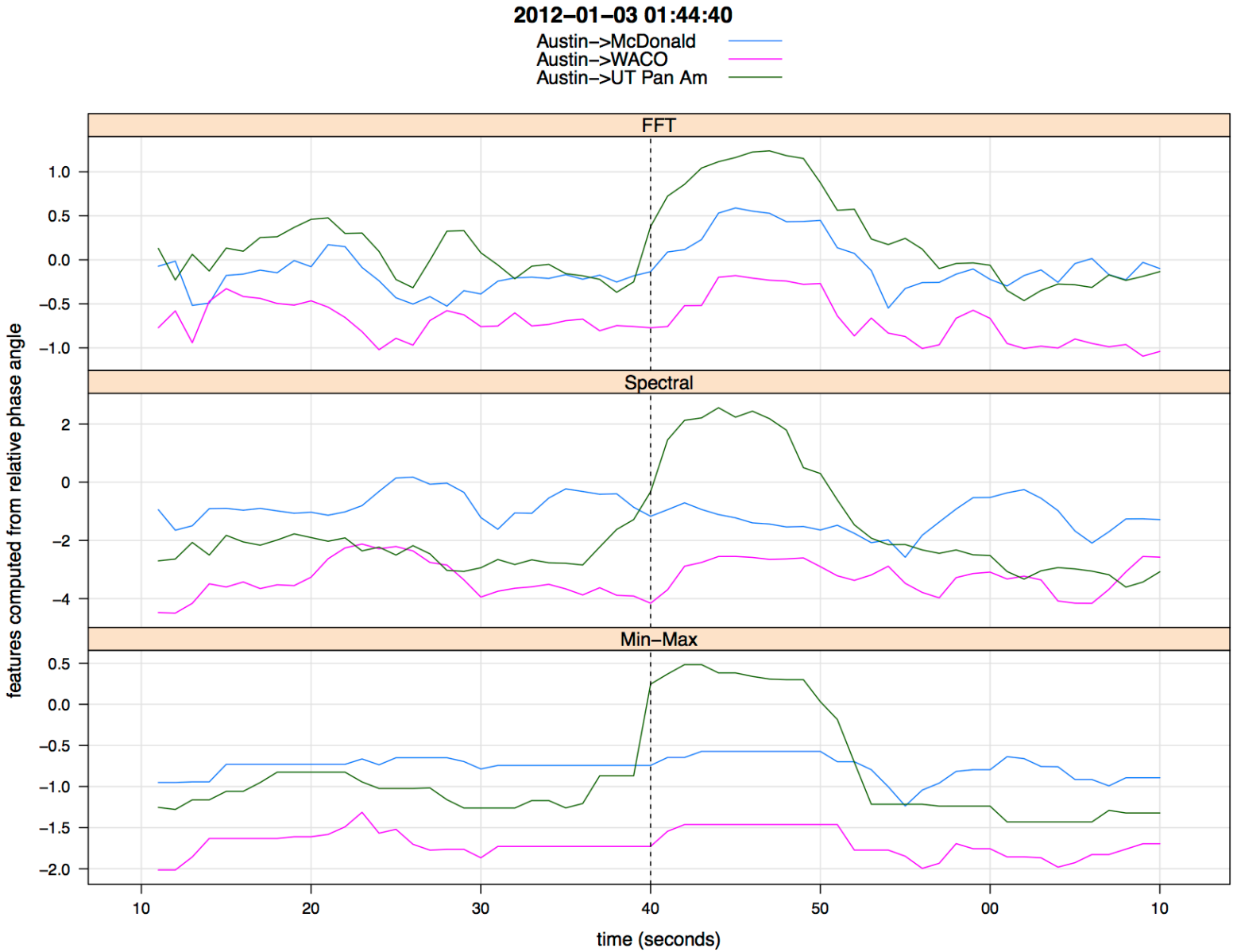

Case Study (2) – global event

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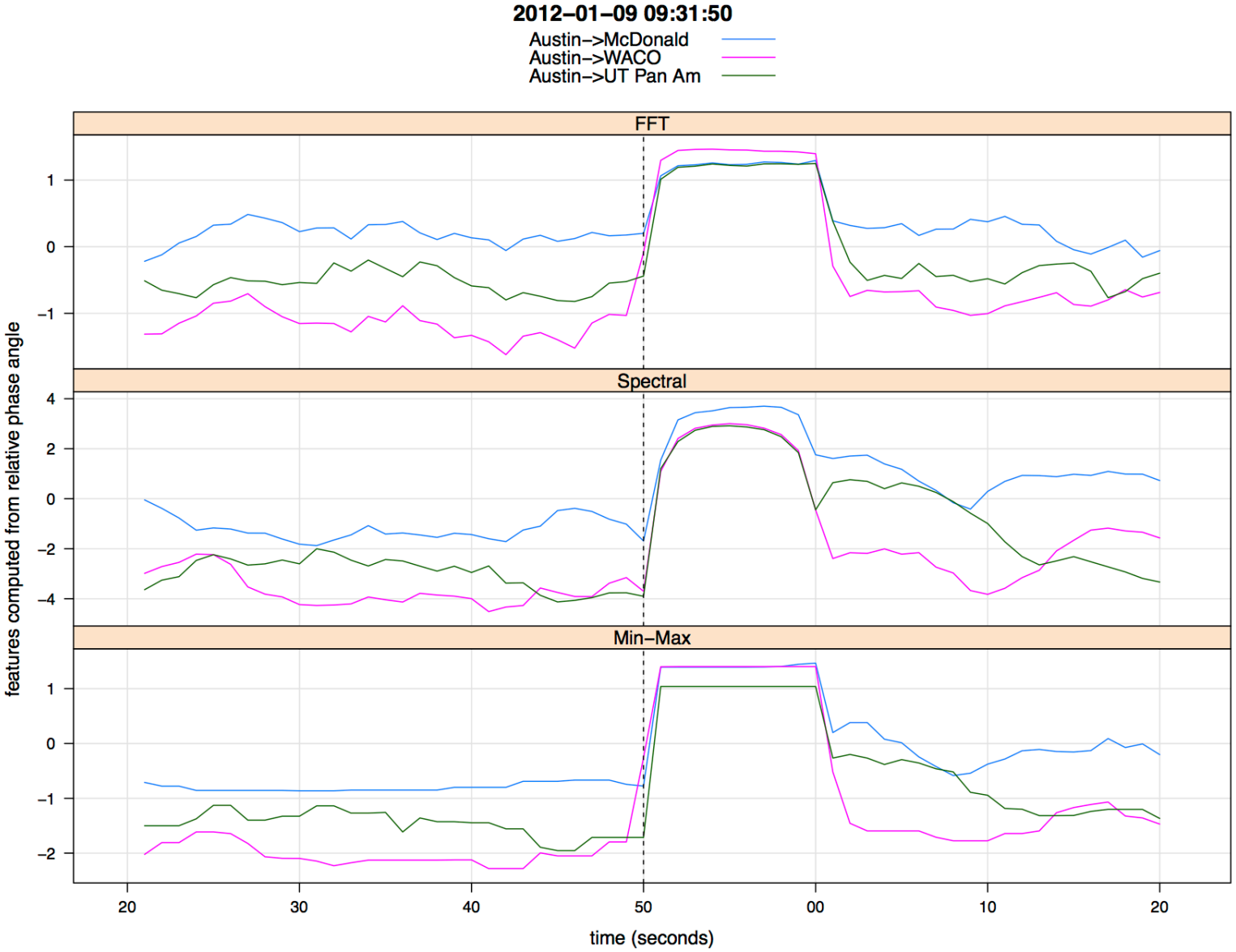

Oscillation Analysis & Stability Evaluation

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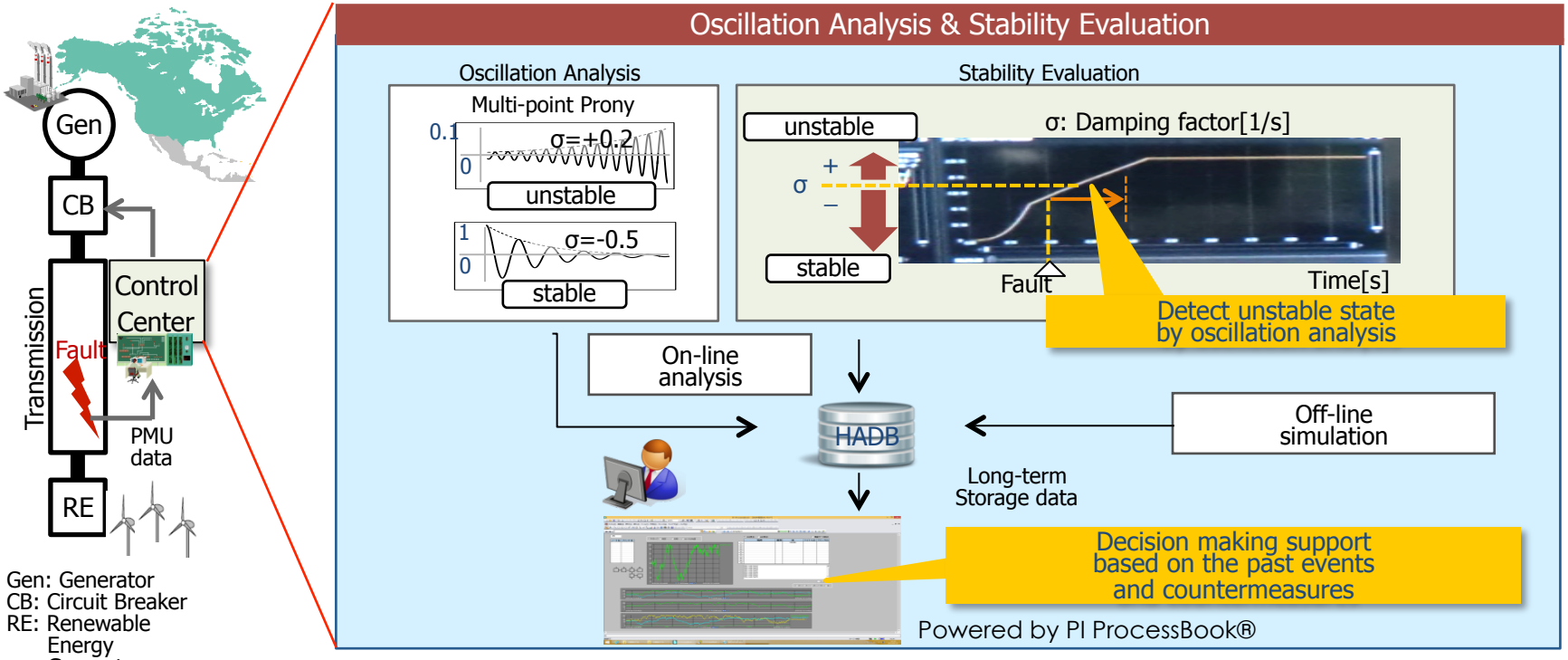
- Detecting disturbances based on both the oscillation analysis and online stability evaluation.
- The oscillation analysis fast detects disturbances and also enables to turn data into "knowledge".
- The stored knowledge will be used for real-time decision making support for operators.



HADB: Hitachi Advanced Database

High-speed data access technology

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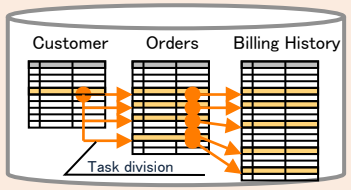
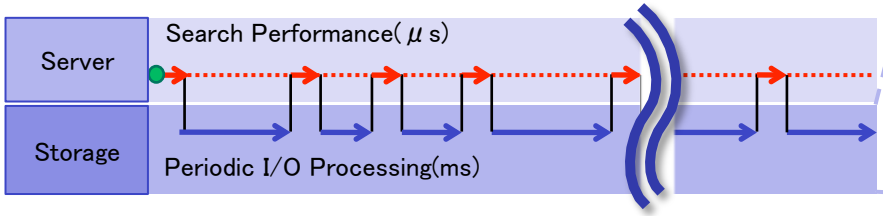
- Fully utilizes the hardware (server, storage) resources
- SQL processing for DB search is automatically divided and executed with a high degree of parallelism

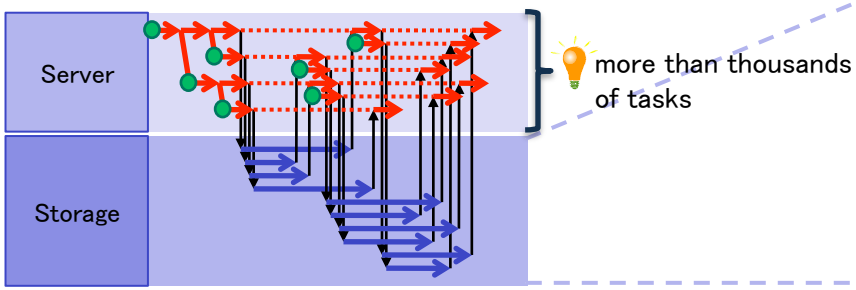
SQL join operation is divided into many search and merge tasks

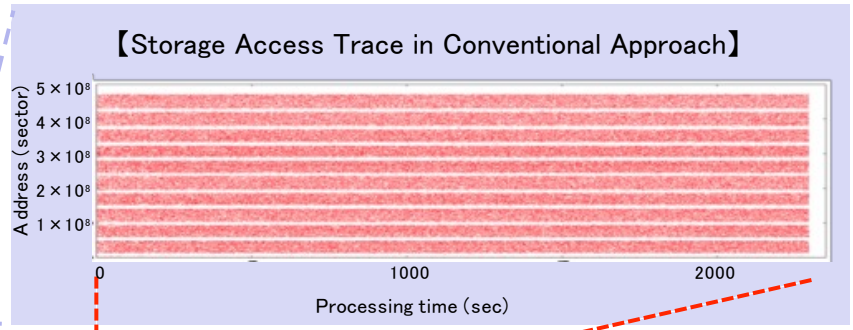


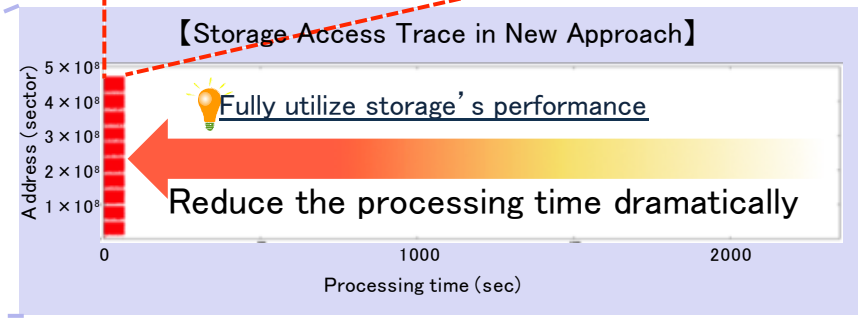
◆[Conventional Approach] Sequential Execution



◆[New Approach] Out-of-Order Execution Principle*1







Task Allocation → Search Processing ⋯ I/O Wait → Disk I/O

Application of the outcome of "Development of the fastest database engine for the era of very large database, and Experiment and evaluation of strategic social services enabled by the database engine" project (Principle Investigator: Prof. Masaru Kitsuregawa, University of Tokyo and also Director-General, National Institute of Informatics), supported by the Japanese Cabinet Office's FIRST Program (Funding Program for World-Leading Innovative R&D on Science and Technology).

*1 A new principle invented by Professor Kitsuregawa and Project Associate Professor Goda (The University of Tokyo).

Typical Queries for PMU Data Analysis

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Two types of Typical query for PMU Data Analysis:

#1: Time-Series Trend Search of several sensors

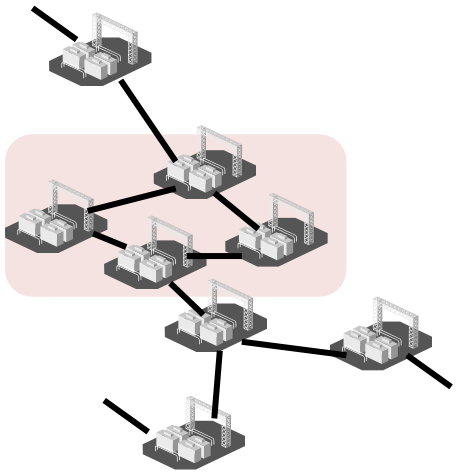
#2: Snap-shot Search from thousands of PMU sensors

Query #1

10 minutes PMU Conform Load Sensor Data for 4 substations

Access Data

10 min x 60 x 30 x 4 sensor
x 4 substation = 288K data



Query #2

All PMU Sensor Data for substations at a specific time snapshot

Access Data

4536 sensors x 5 snapshot = 23 K data

Evaluation Results

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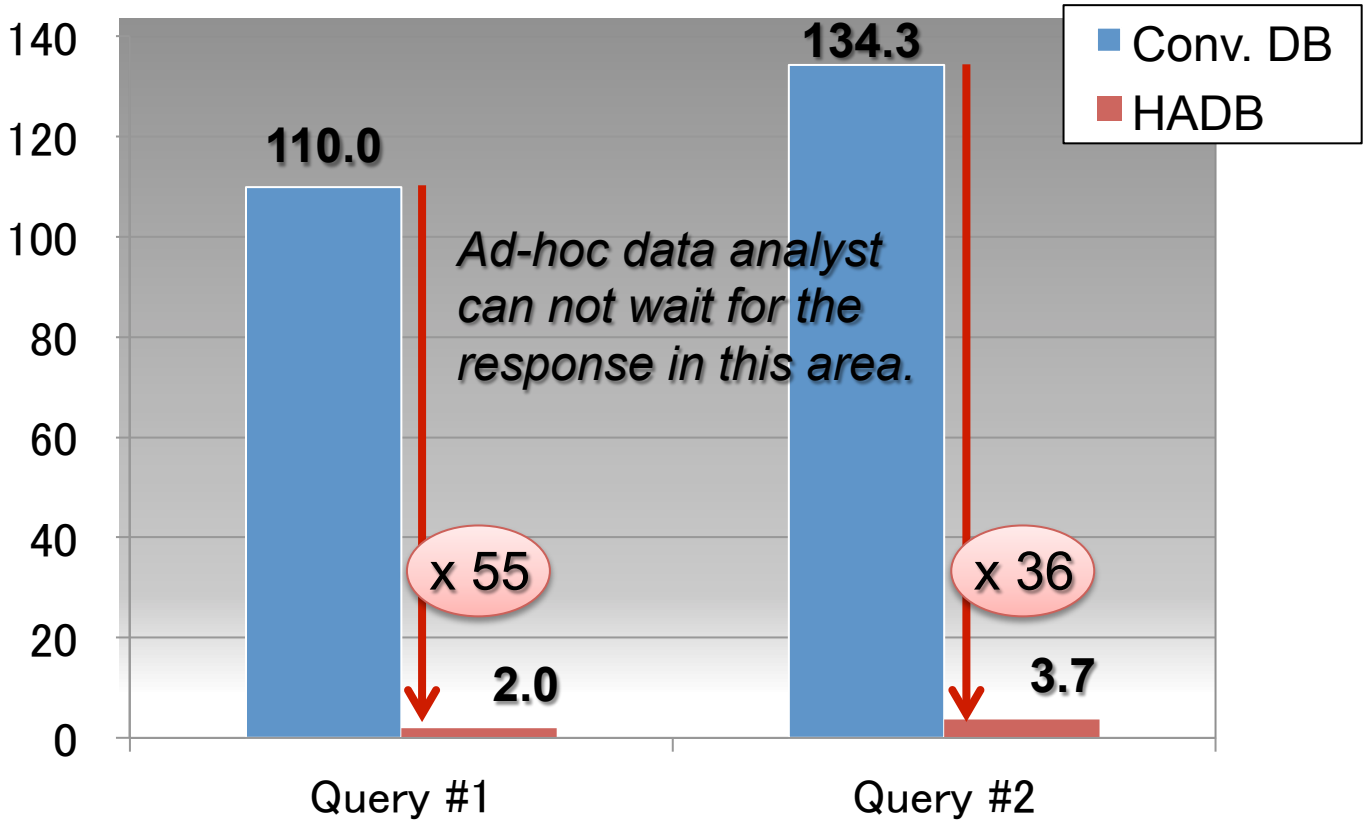
In conventional DB, both queries took more than 100 sec.
--- Ad-hoc data analysts can not wait for the response of these queries.
HADB improves the typical query performance by x36-55.



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Live Demo

- PMU Application for Control Center
- Wide area visualization
- Event Detection
- HADB

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- Decision Support System
  - Detecting, locating, and classifying disturbances
  - Correlation techniques to identify cascading failures
  - Countermeasures
- Big Data Platform for PMU data
  - Real-time Data Processing
  - Historical Data Analysis


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