Advances in Synchrophasor-Based Wide Area Defence and Control

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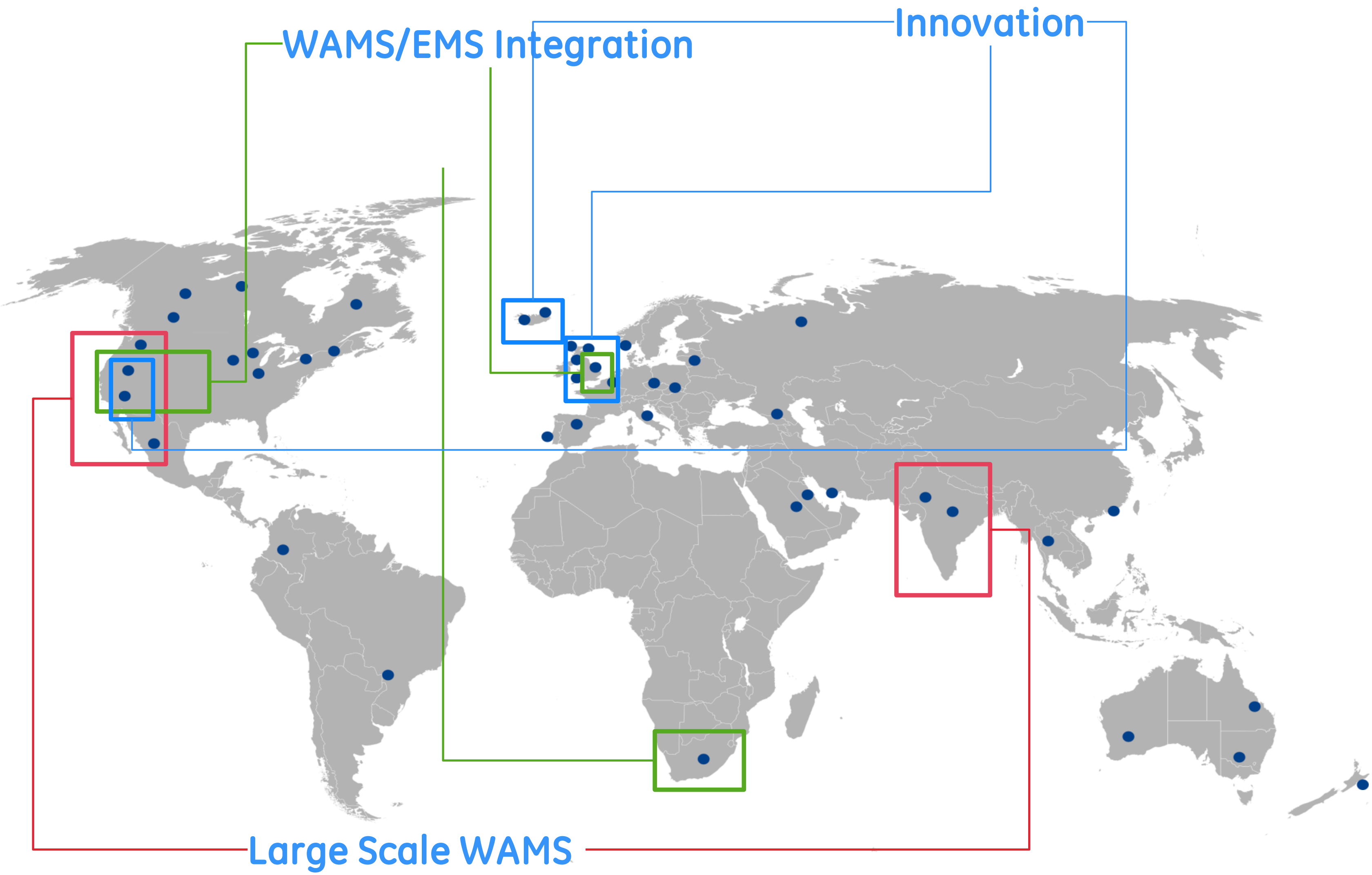
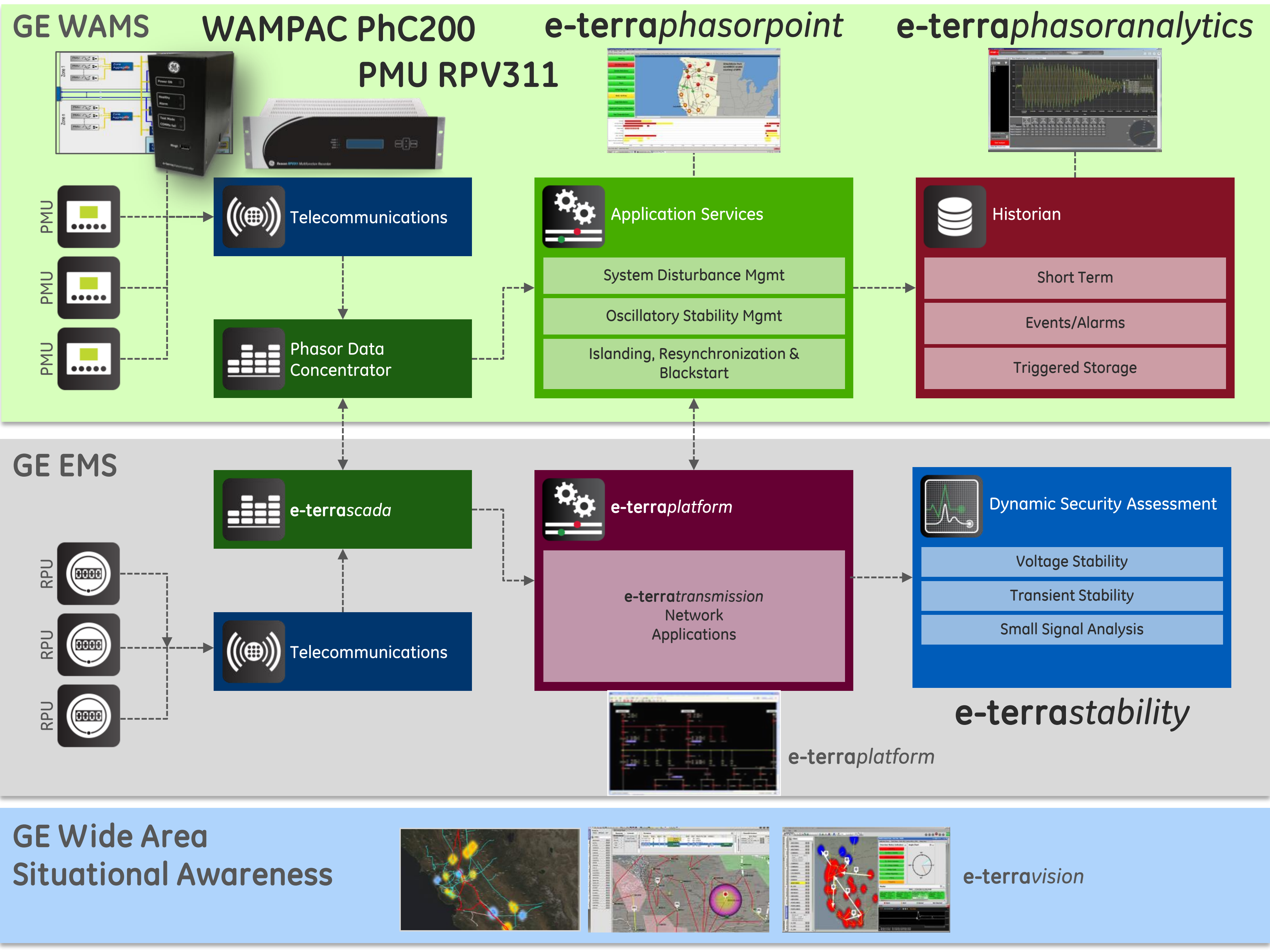
Our Customers





GE WAMS
WAMPAC PhC200
PMU RPV311
e-terraphasorpoint
e-terraphasoranalytics
PMU
PMU
PMU
Telecommunications
Phasor Data Concentrator
Application Services
System Disturbance Mgmt
Oscillatory Stability Mgmt
Islanding, Resynchronization & Blackstart
Historian
Short Term
Events/Alarms
Triggered Storage
GE EMS
e-terrascada
RPU
RPU
RPU
Telecommunications
e-terraplatform
e-terratransmission Network Applications
Dynamic Security Assessment
Voltage Stability
Transient Stability
Small Signal Analysis
e-terrastability
e-terraplatform
GE Wide Area Situational Awareness
e-terravision

What is WAMS useful for?

Control Design

PSS/POD tuning

GOV tuning

Cause analysis

Auto-action design

OPS Procedures

LONG-TERM

Improve Dynamic Performance

Early Warnings

Angles diverge

Oscillation alarms

Precursor events

PRE-EVENT

Reduce Contigency Probability

Faster Restoration

Situational awareness

Island reconnection

Stabilisation

Stress reduction

Post-event analysis

POST-EVENT

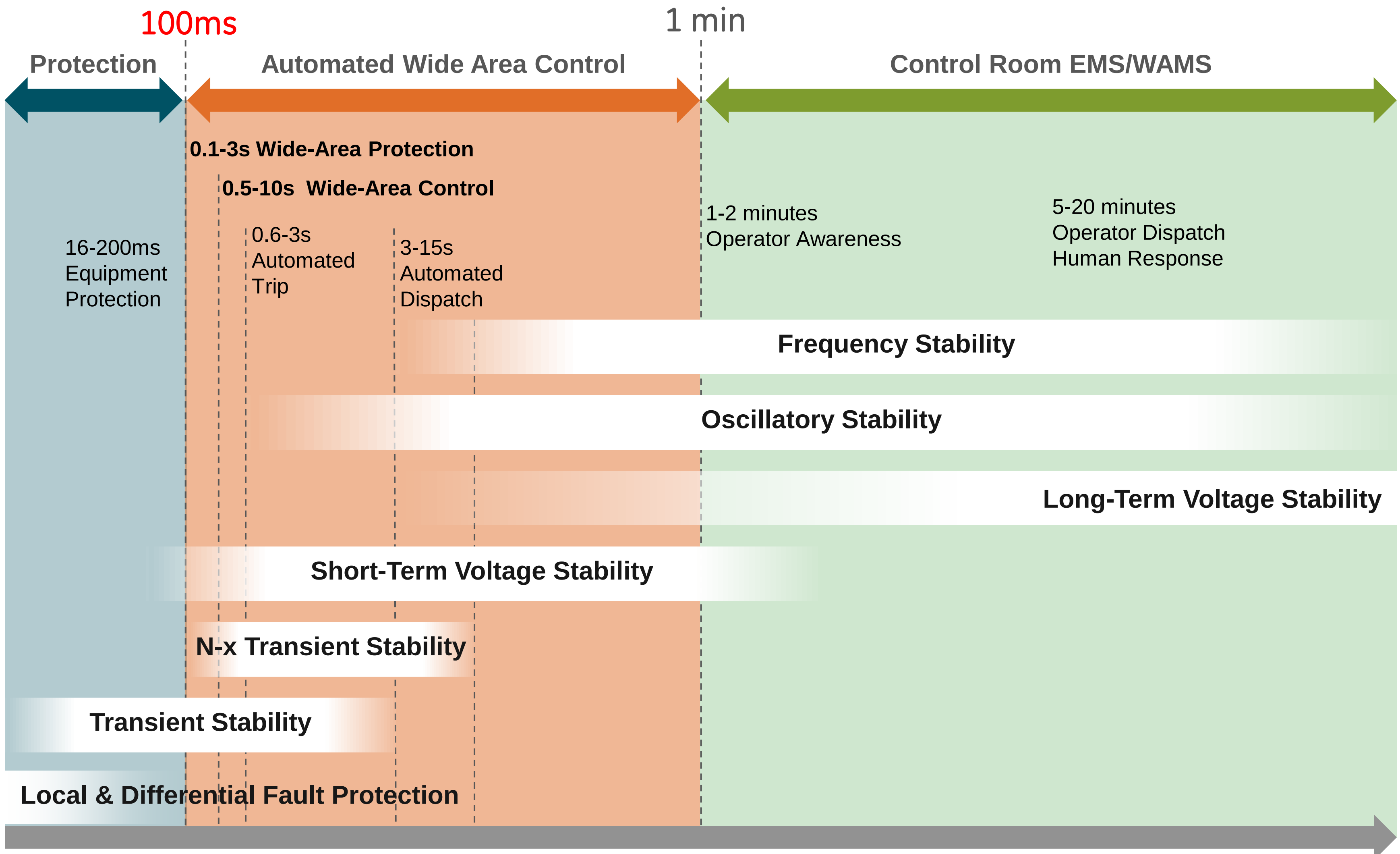
Reduce Impact of Disturbances

WIDE-AREA CONTROL

Protection Schemes:
Event-based x Response-based

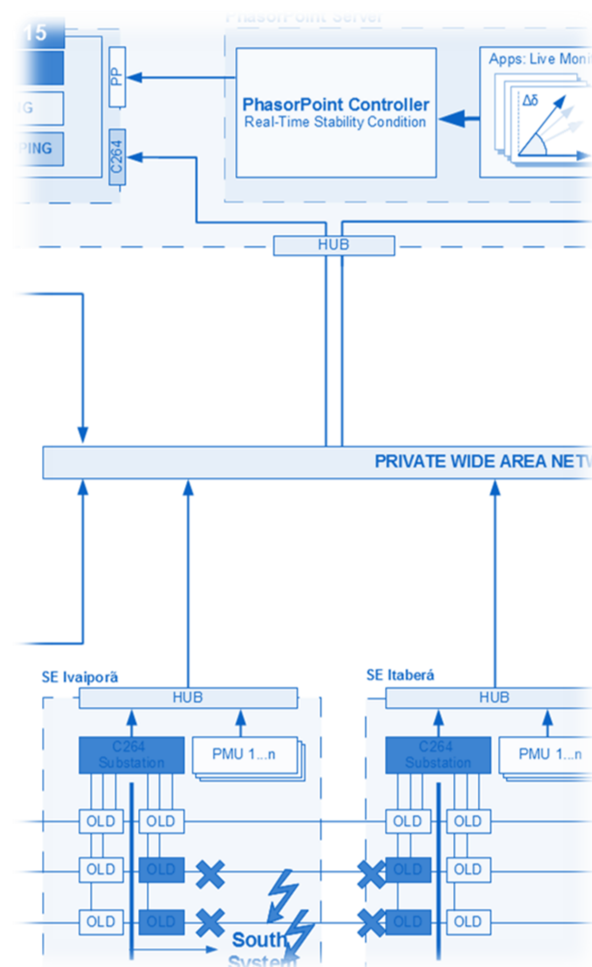
Wide Area Monitoring, Protection & Control

Bridging the grid control gap!



1) SIPS Event-Based

- Fast Reponse (< 200ms)
- Transmission bandwidth requirement is potentially lower
- Direct detection of pre-selected outages
- Design is model-based
  - Design is deterministic and therefore doesn't cater for all eventualities
  - More measurements required (expensive)
  - Doesn't always adapt to system conditions
  - Over-conservative triggering is a possibility
- Maintenance procedures must ensure scheme is disabled



Example: Power corridor trips => Switch(es)/Breakers=0

2) SIPS Response-Based

- Detection of system <u>phenomena</u>
- Can adapt to system conditions
- Can cater for eventualities that weren't even studied directly
- Potentially requires less measurement points to detect the phenomena
- Transmission bandwidth requirement is higher
- Continuous vs Discrete control output

Example: Power corridor trips => P=0

3) SIPS Wide Area / Principles

- Protect system supply
- Take undesired action to prevent worse/cascading events

  'Sacrifice the few to benefit the many'

- Avoiding conservative actions – Adaptive Scheme

Design goals:

- Take just the right amount of action

  'Not too much, not too little'

- Do not mal-operate
- Reliability

  'Can the operator trust that this is going to save them if they need it'

PhasorController ™ PhC 200 series

Programmable controller platform, Remedial Action, Special Protection Schemes, Synchrophasors.

Protection & Control

- Event-based localised SIPS; for example inter-tripping schemes based on topology
- Advanced local/centralised SIPS without phasor data; for example transient instability protection schemes
- Phasor-based control or security schemes; for example PMU based out-of-step protection and island balancing schemes

Flexibility

Create, tailor and adapt control schemes as the power system evolves

- Field-engineer friendly deployment
- PLC environment (IEC 61131-3)
- Remote/online configuration settings management through IEC 61850

Connectivity

- IEEE C37.118.2 2005 & 2011
- IEC 61850 (MMS & GOOSE)
- IEC 60870-5-104
- DMP3
- Modbus
- Digital IO
- Analog IO

Reliability

- **Hard-real time, fully deterministic execution with execution cycles from 4ms up to 20ms.**
- Meta-data makes data quality inherent to each signal
- 'Graceful degradation' using meta-data ensures scheme operation even with lowered quality of input signals
- Fully integrated with **e-terra***phasorpoint*™ for monitoring of scheme status, internal signals and performance

Key differentiators

Wide Area and Local Measurement Inputs
Multiple IEEE C37.118 synchrophasors (from PMUs, PDC)
IEC61850 data – GOOSE and Reports

Fast measurement- and event-driven control applications
Target controller own latency 4-20ms

Complex algorithms – high efficiency
Through the use of expert-designed Application Function Blocks (AFBs)

Highly configurable, field-engineer friendly deployment
IEC61131 PLC environment to construct specific controller schemes
AFB library for complex functions
Standard IEC61131 PLC elements for user customisation

Native IEC61850 combined with IEC61131
Each AFB is associated with its own IEC61850 Logical Node (LN)
Settings can be configured from any IEC61850 client

Graceful Degradation – CRITICAL FOR WIDE AREA CONTROL
Built-in utilisation and propagation of Signal Metadata
Dynamic adjustment of the controller performance based on data quality

Key Technologies in modern Power Systems

- **IEEE C37.118 Synchrophasors (PMUs, PDC, …)**
  - configurable measurements (V, I, phase, …)
  - configurable sampling frequency

- **IEC 61850 (MMS, GOOSE, …)**
  - SCL data-model describes power system comprising many IEDs: discoverable, navigable for monitoring and config/control
  - Configurable low-latency data-attribute distribution
  - fine-grained model for each IED comprising both predefined and bespoke LNs
  - Vendor inter-operable (IEDs and tool-chains)

and …

- **IEC 61131-3 PLC**

Existing WAMPAC Example

Customer A – Application Examples

Control of all smelter loads

- Fast down & up regulation
- Balance action within disturbance area
- Goal to prevent system split

Fast ramping generating units

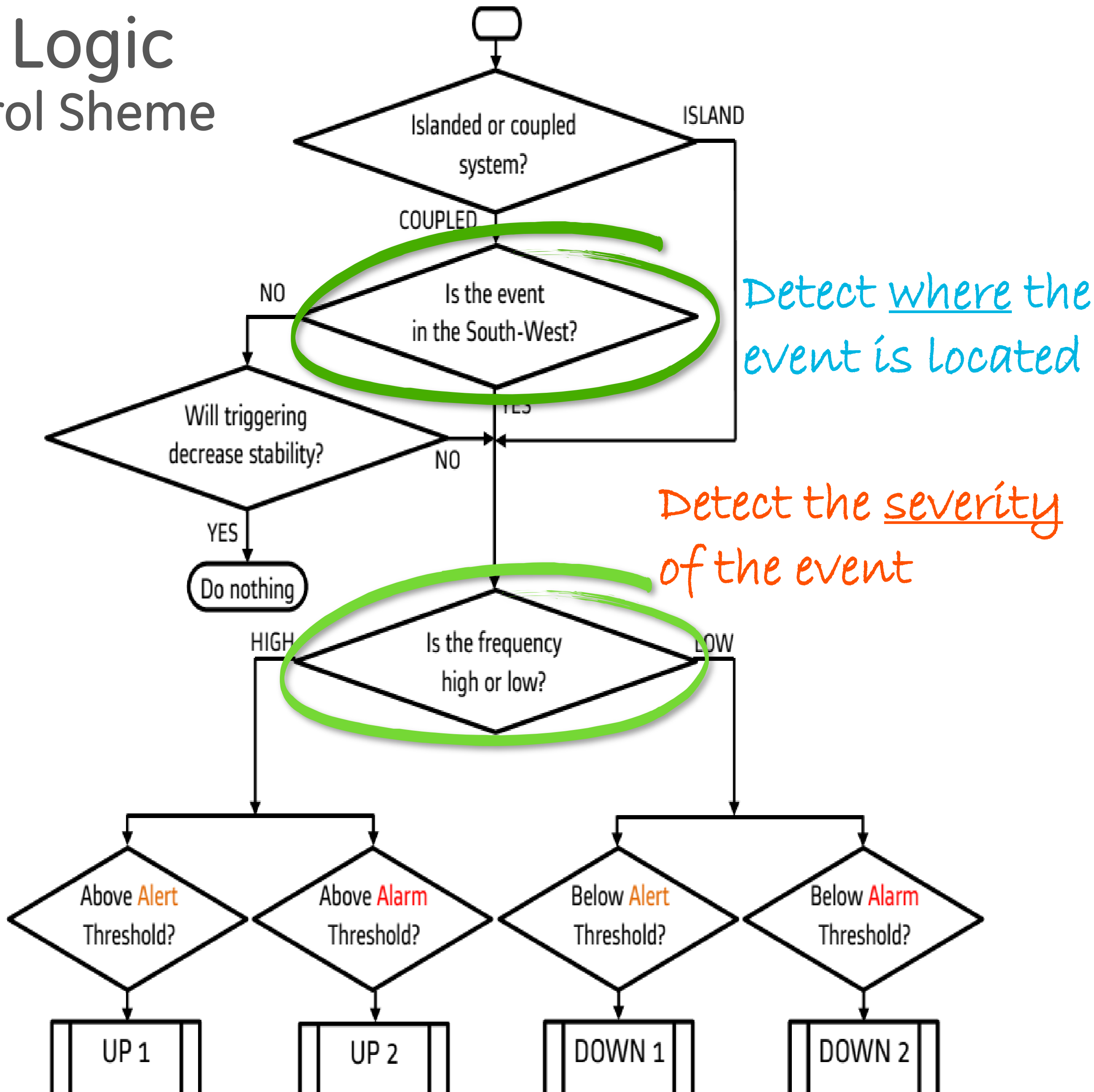
- Faster response within disturbance area, reducing frequency change
- PMU based blocking of change over to frequency mode
- Emergency control in AGC

Intelligent Islanding

- Split-line armed depending on power flow and balance
- Intelligent splitting points at generator buses
- Increased power flow on 132 kV ring

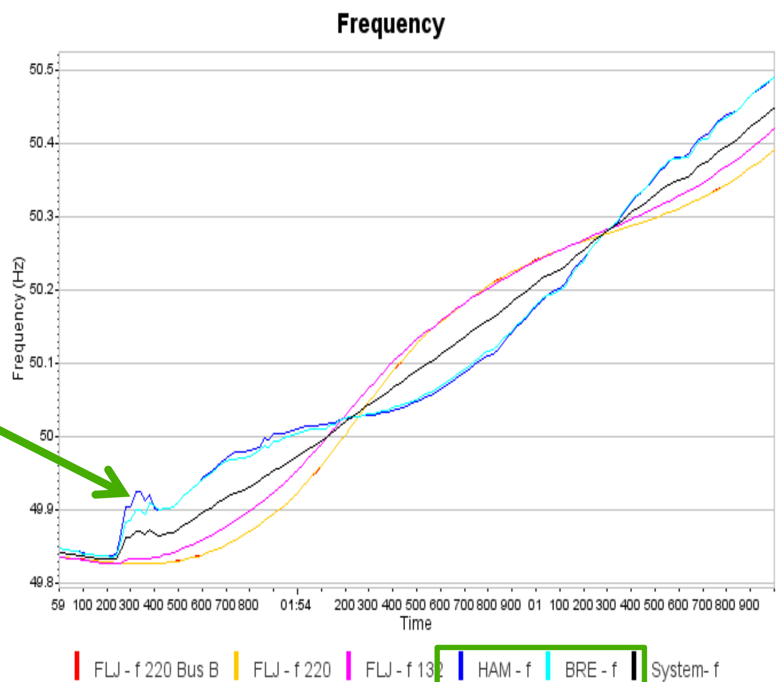
Scheme Logic

Load Control Sheme

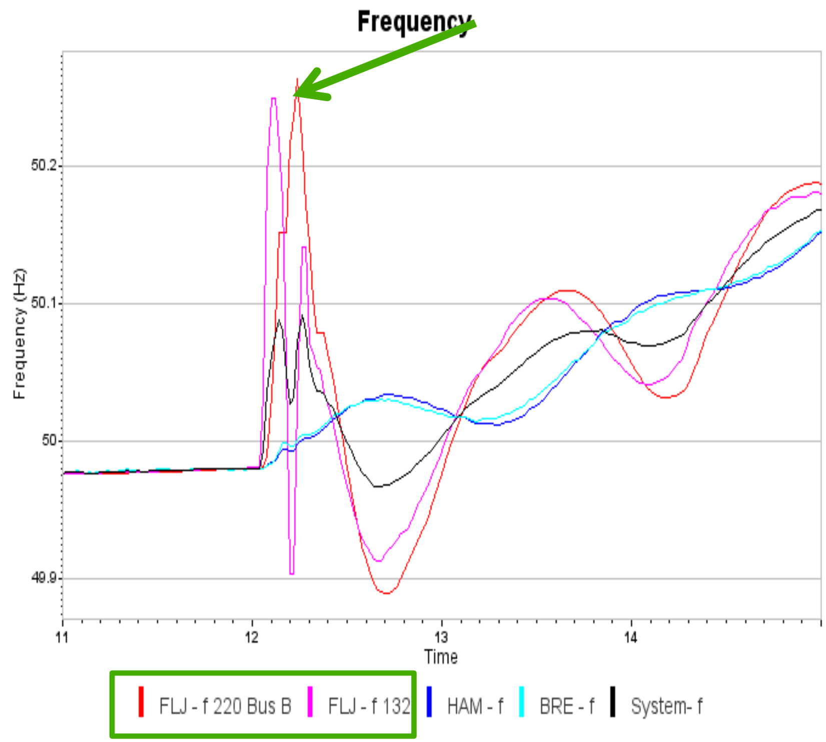


Event Location Detection
Load Control Sheme

The frequency signals near to the event location move first



Load trip in the WEST



Load trip in the EAST

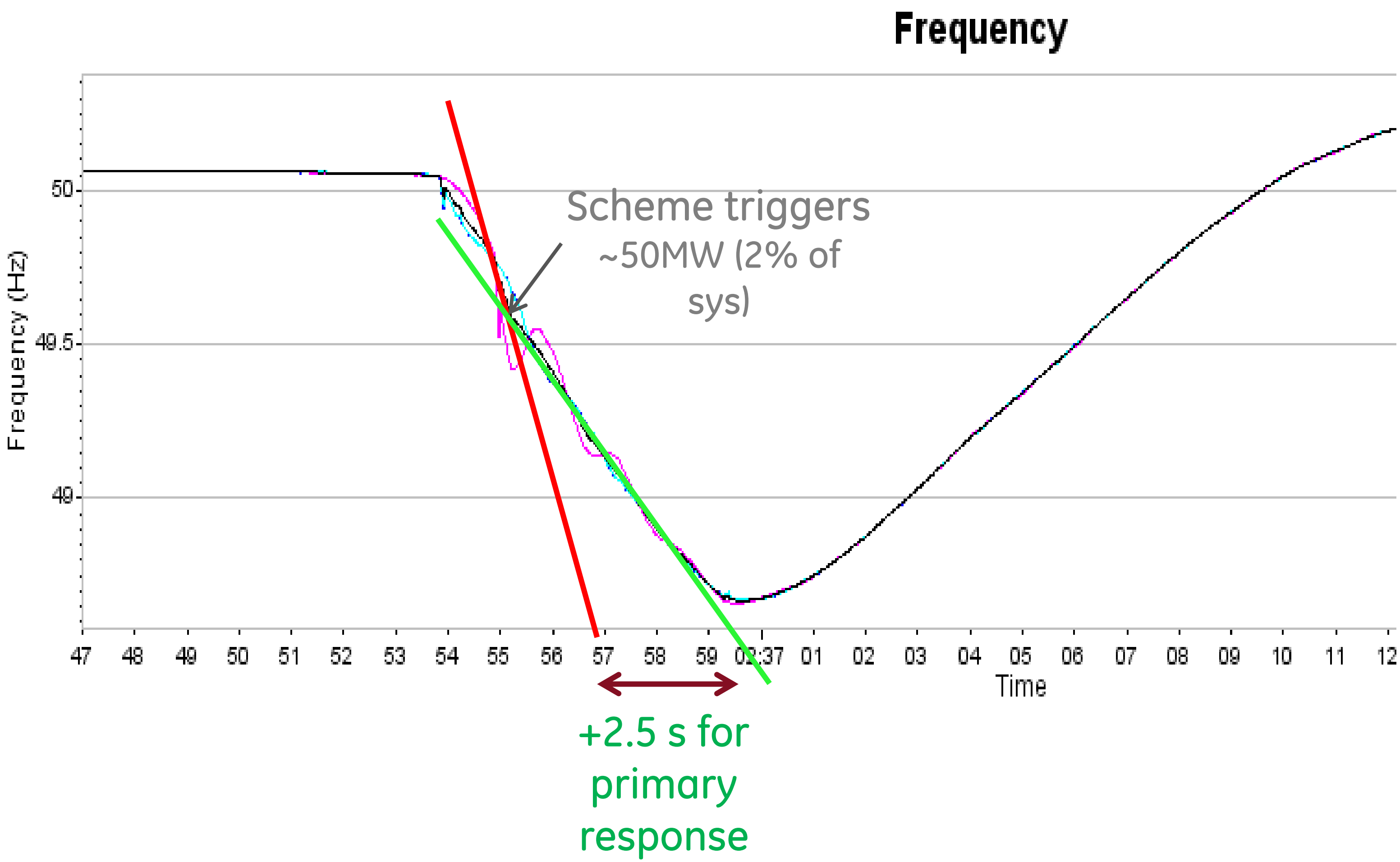
Scheme Logic
Load Control Sheme

	ROCOF +	ROCOF -
WEST_EAST Δf +	WEST Load loss ENABLE: Always	EAST Gen loss BLOCK: $+\Delta\partial$ ENABLE: $-\Delta\partial$
WEST_EAST Δf -	EAST Load loss BLOCK: $-\Delta\partial$ ENABLE: $+\Delta\partial$	WEST Gen loss ENABLE: Always

Power going from EAST to WEST

Power going from WEST to EAST

Frequency response improvement

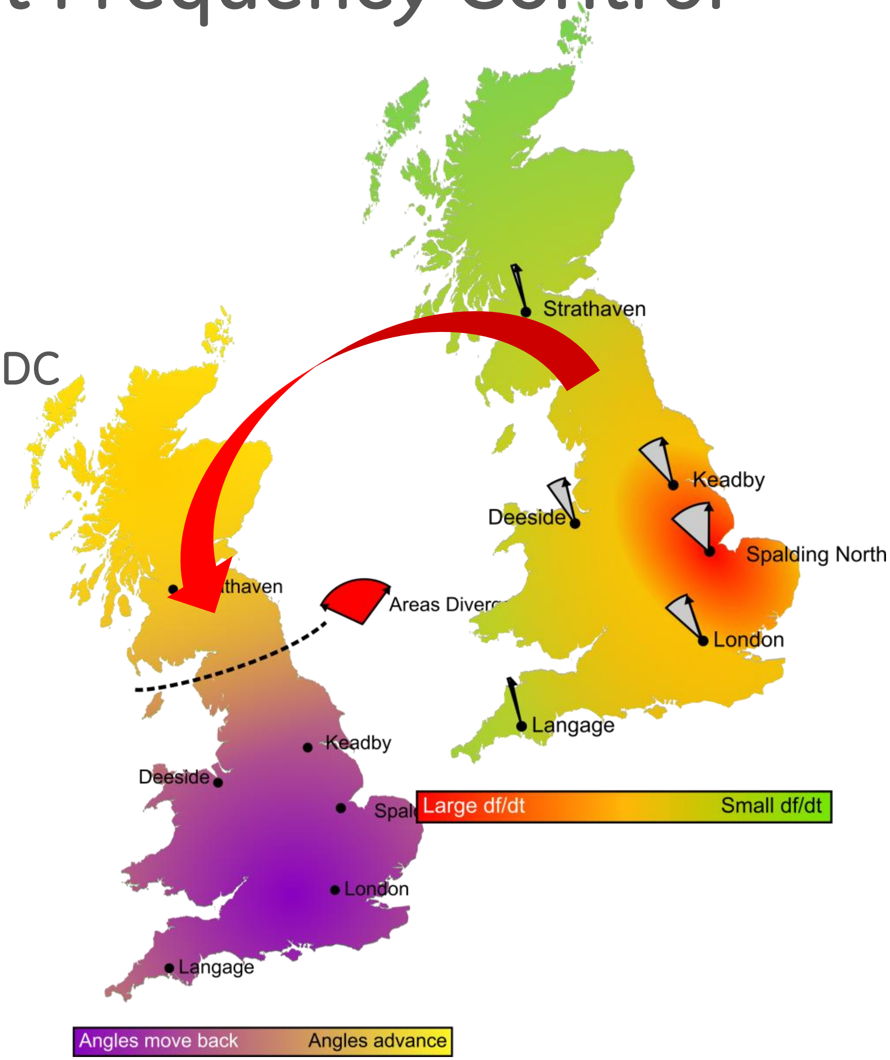


Summary

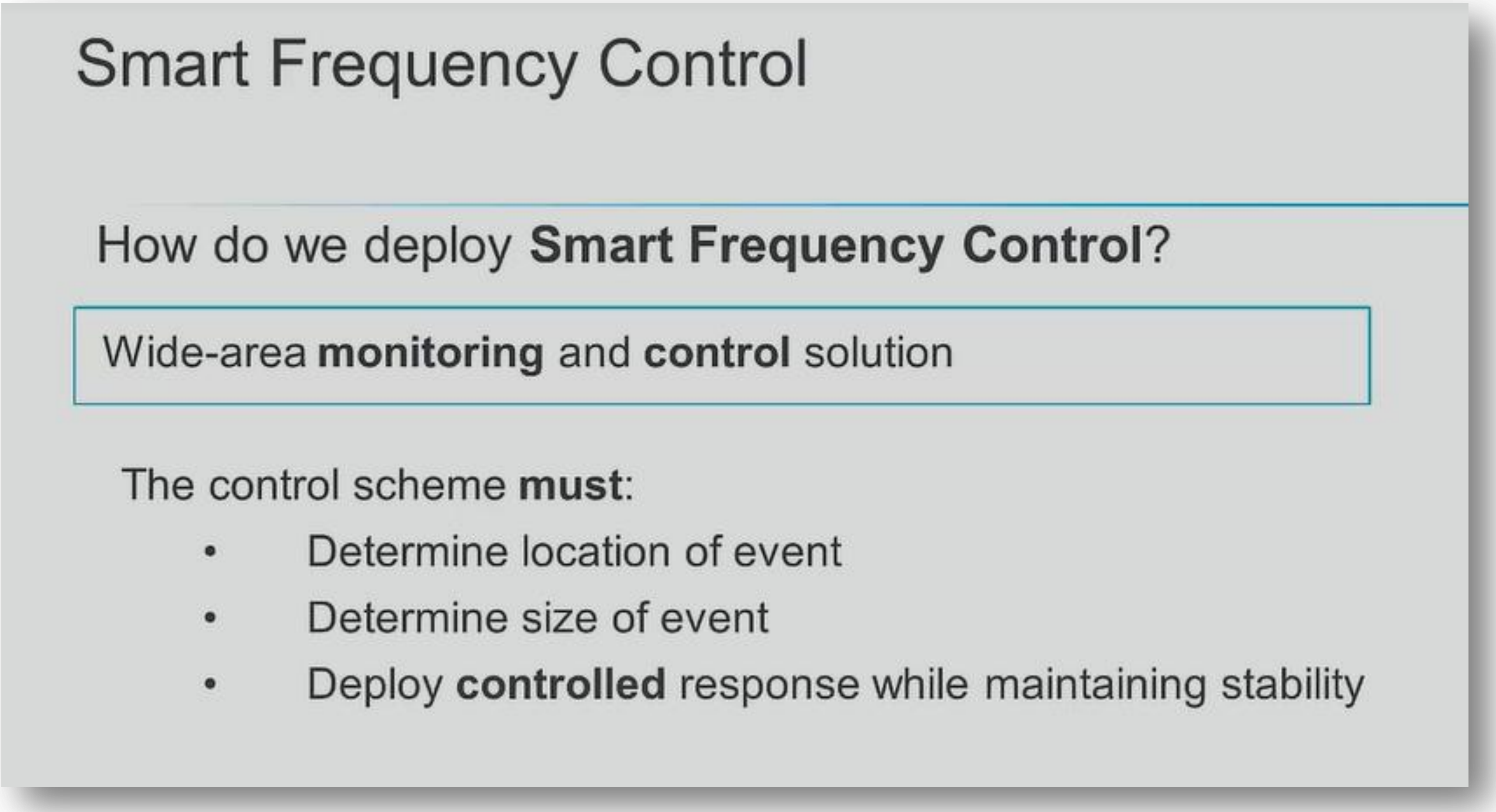
- Installed and operational for over a year
- Uses PMU signals from throughout the country (>300 km)
- Response times
  - ~60 ms for direct trigger
  - ~600 ms based on system response
  - ~600 ms smelter 'ramp' rate
- PhC100 technology, PhC200 would be faster and more deterministic
- Customer pleased
  - Busy implementing on more plant (PhC200)
  - Looking at redundancy as scheme penetration increases

Customer B – Frequency Stability: Addressing Inertia Reduction → Smart Frequency Control

- Address low-inertia faster frequency response to disturbance
- Improve transmission boundary capacity
- Reduce risks of disturbance & oscillation
- Manage risks with series capacitance / HVDC additions
- Improve knowledge
- Reduce cost of Frequency Control
- Use non-conventional fast-response capability



Video – Smart Frequency Control



Final Remarks

WAMPAC: Stakeholder Benefits

Transmission

- Reduce event impact and risk of protection maloperation

Generator

- Reducing on-load trip events, increasing generator availability

System Operator

- Reduce generation loss and accelerate restoration/avoid system outages in complex scenarios

Distribution

- Special Control Schemes
- Enhance Renewable Penetration

Obrigado!

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GE WAMS

WAMS is no longer just a 'laboratory tool'

- Innovation Projects, EMS Integration, Large Scale WAMS and WAMAPAC Schemes have/is being deployed by GE.

GE is taking WAMS to the next generation EMS

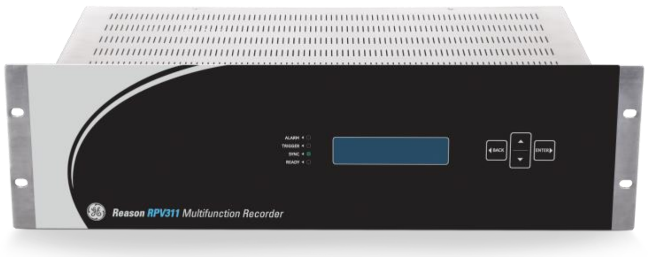
- providing optimization opportunities and decision making support

GE is shaping the technology of WAMPAC schemes

- deliviring a unique platform specially tailored for the purposed.

PMU – RPV311|RA

Digital fault recorder with PMU or Independent PMU



The Reason RPV311 is the most powerful electrical system monitoring, recording and analysis device. Phasor measurement, power quality, precision fault location and process bus options deliver the highest integration capabilities for digital substation and wide-area schemes (WAMS)

- Phasor Measurement Unit (PMU) in accordance with IEEE C37.118.1/2-2011/1a-2014
- **Wave Measurement Unit (WMU) - Wide-area subcyclic oscillations**
- Fault recorder
- Disturbance recorder
- Continuous recorder (waveform and RMS)
- Steady-state recorder
- Sequence Of events recorder
- Real time monitor
- **Travelling wave-based fault locator (TWFL)**
- Process bus (IEC61850-9-2LE) recorder
- DC to 3 kHz measurement
- IEC 61850-8-1 support

PMU functionality can be easily enabled in the GE-Reason DFR already installed!