PMU Applications Prioritization Methodology Based on Wide-Area Disturbance Events and its Implementation in the Colombian Electric Power System

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Background

- Under a grant from the United States Trade and Development Agency (USTDA), Quanta Technology worked with XM Colombia in the development of an advanced control system for the Colombian transmission grid.

- Quanta provided:
  - Conceptualization and design for the implementation of a Wide Area Measurement System for the Colombian power grid.
  - Objective: improve observability and control of the National Interconnected System in Colombia by using PMU measurement and advanced PMU applications

- Expectation: XM will improve quality and reliability of its operation, measured by
  - Reduction in the number of events that affect the demand and
  - Improvement of the operation Key Performance indices.

iSAAC Conceptual Diagram
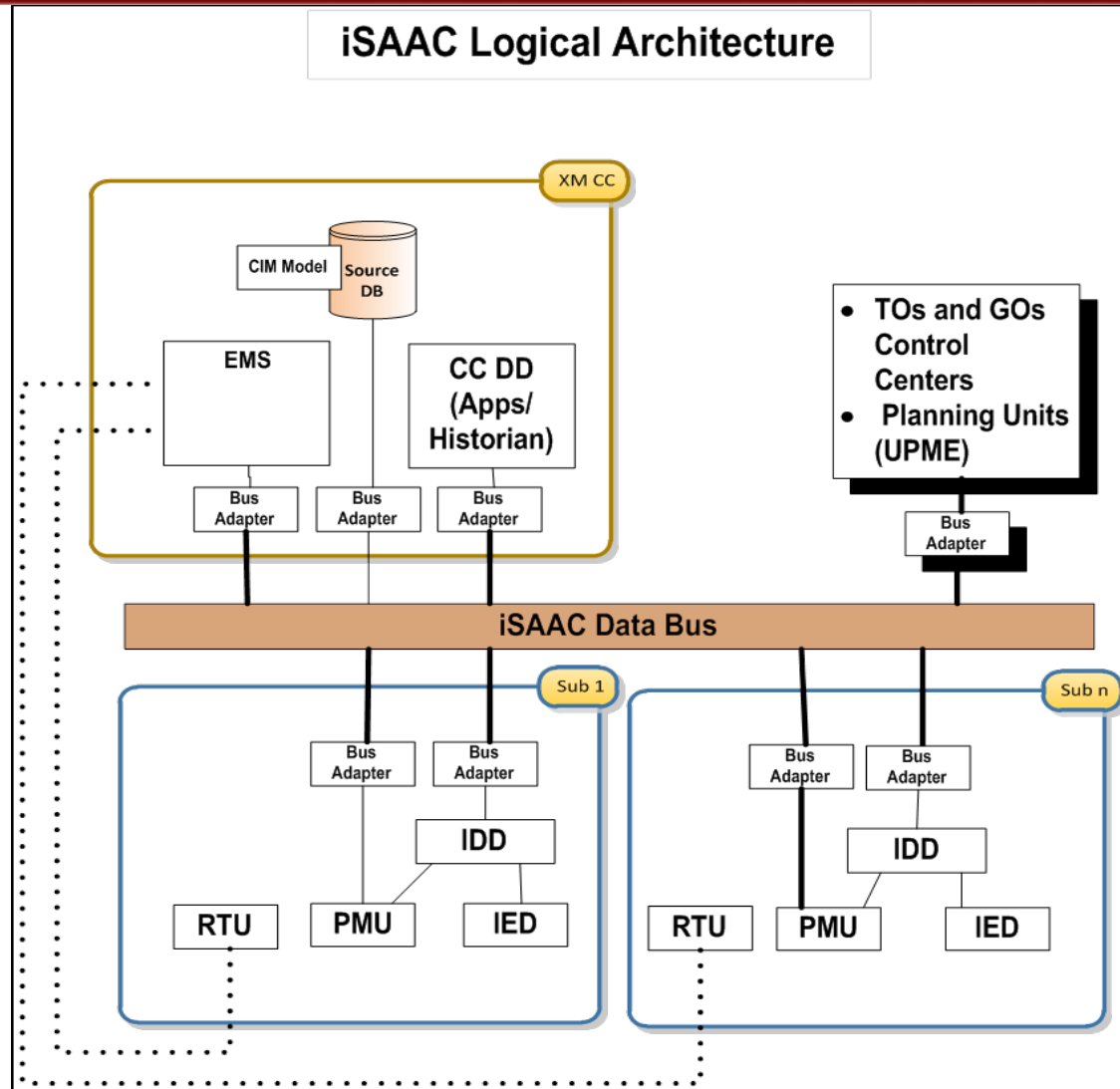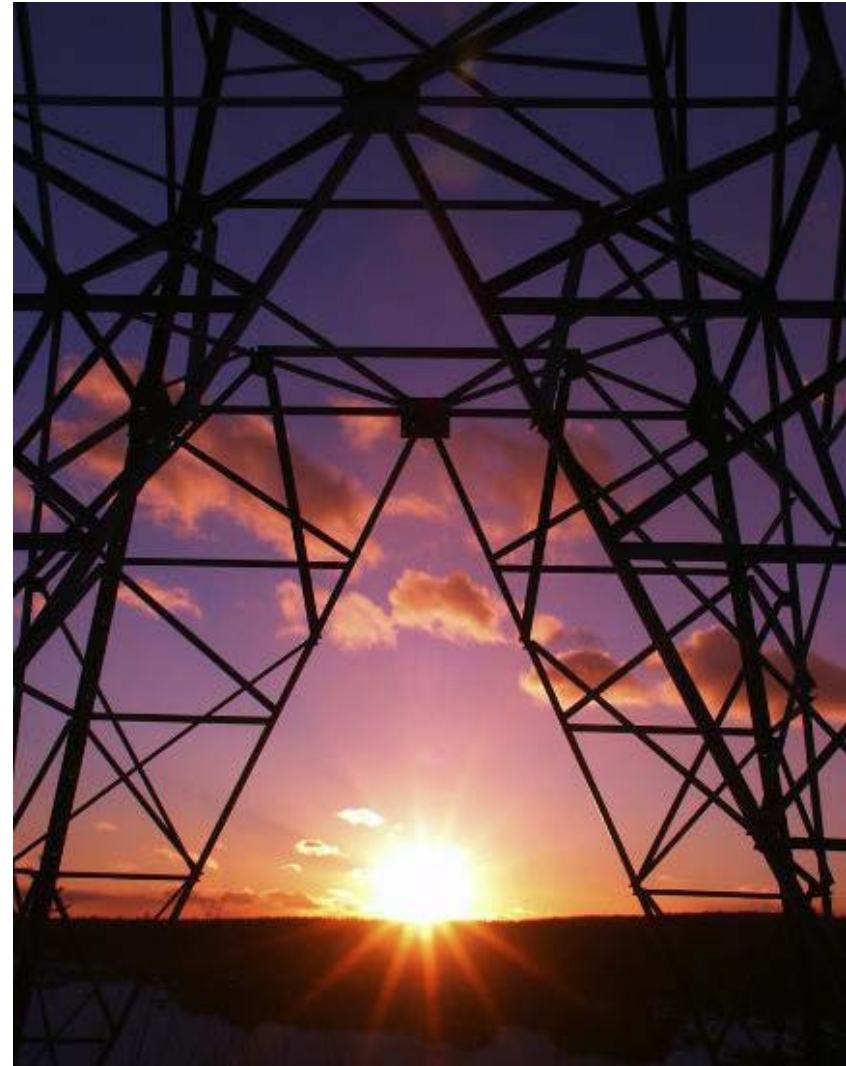
Identified PMU Applications

- Real-time applications
  - Advanced applications for system protection (includes SIPS) and out of step protection)
  - Advanced Situation Awareness (ASA) (includes EMS and phasor management system)
  - Collaborative protection
  - Complex event processing
  - Distributed state estimation
  - Frequency monitoring and control
  - Local control
  - Oscillation monitoring
  - Power flow monitoring
  - Real time data validation
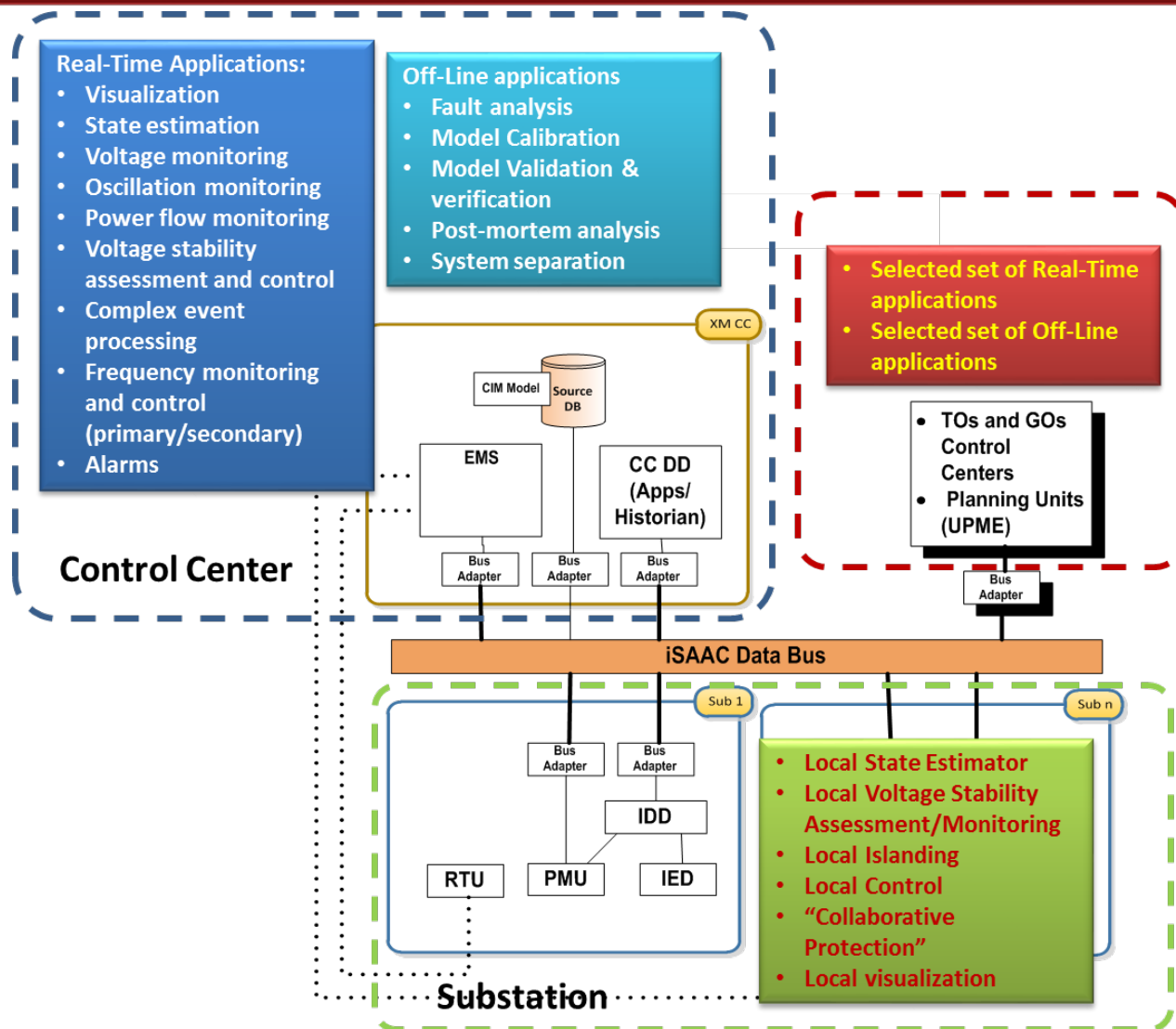 - Voltage stability monitoring

Identified PMU Applications

- Off-Line applications
  - Baselining
  - Model calibration and validation
  - Operator training simulator
  - Post-mortem event analysis
  - Synchrophasor system simulator
 - System separation - islanding

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Applications Location Assignment

Real-Time Applications:
- Visualization
- State estimation
- Voltage monitoring
- Oscillation monitoring
- Power flow monitoring
- Voltage stability assessment and control
- Complex event processing
- Frequency monitoring and control (primary/secondary)
- Alarms

Off-Line applications
- Fault analysis
- Model Calibration
- Model Validation & verification
- Post-mortem analysis
- System separation

Control Center

XM CC

CIM Model | Source DB

EMS

CC DD (Apps/Historian)

Bus Adapter | Bus Adapter | Bus Adapter

- Selected set of Real-Time applications
- Selected set of Off-Line applications

- TOs and GOs Control Centers
- Planning Units (UPME)

Bus Adapter

iSAAC Data Bus

Sub 1

Sub n

Bus Adapter | Bus Adapter

IDD

RTU | PMU | IED

- Local State Estimator
- Local Voltage Stability Assessment/Monitoring
- Local Islanding
- Local Control
- "Collaborative Protection"
- Local visualization

Substation

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Selection Criteria for Implementation

- Three criteria to identify and prioritize synchrophasor applications:

Application Readiness for Deployment

System Need

Additional Effort to Implement
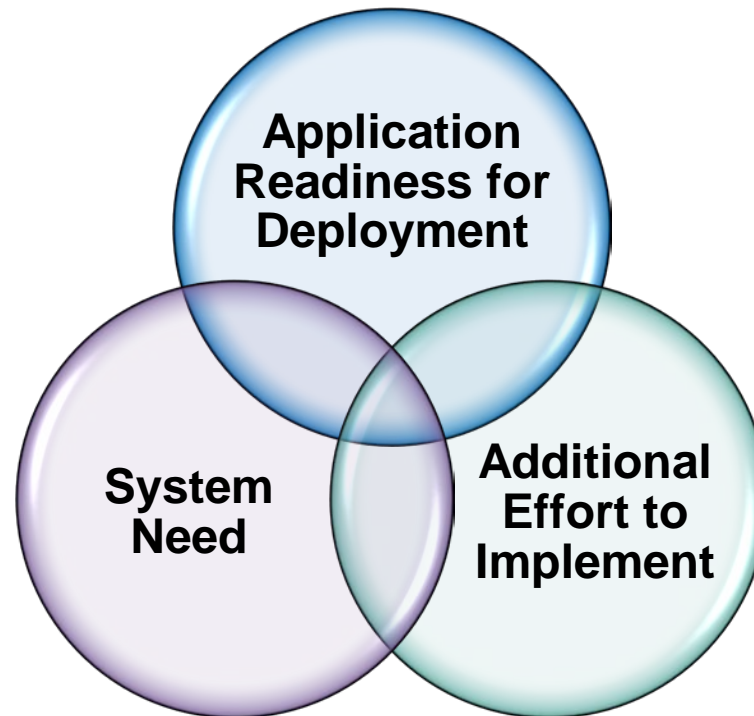
Criterion: Power System Need

- System need was identified as the most important criterion. The score based for System Need is defined as follows:
  - Weight of 1: Low. Helps but not critical for mitigation of the weaknesses of the system.
  - Weight of 2: Medium. Helpful to have but not necessary.
  - Weight of 3: High priority. Critical application that could greatly help to mitigate system events.
- The system need was defined based on the wide area disturbance event analysis of a significant number of events in the past 5 years

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Criterion: Power System Need

- An example of the mapping of the recommendation:

Wide Area Disturbance Analysis	Corresponding PMU Application
Out of step	Advanced applications for system level phenomenon (includes SIPS and out of step protection)
Improvement in interconnection	Advanced applications for system level phenomenon (includes SIPS and out of step protection)
Monitoring to study system dynamics. SCADA reporting rate is not adequate	Oscillation monitoring
Determine safe generation limits for stressed system conditions	Base lining power system, model validation and calibration
Power system modeling and fine tuning	Model validation and calibration
Verification of generators frequency contributions	Model validation and calibration

Criterion: Readiness for Deployment

Based on maturity of the application. The scores used for this factor are:

- Weight of 1: Concept and R&D. It refers to applications that are still in conceptual stage and involve additional R&D.

- Weight of 2: In product development phase. The applications that are not fully developed, or are still in the test phase.

- Weight of 3: Commercially off-the-shelf (COTS) product available. Applications ready for deployment; vendor support available.

Criterion: Additional Effort to Implement

- Required additional effort to implement
  - <u>Weight of 1</u>: Additional infrastructure for deployment / expansion required
  - <u>Weight of 2</u>: A procurement and commissioning process required
  - <u>Weight of 3</u>: Development of supporting operation processes/procedures and user training required.

- The scores for all previously discussed factors are captured and computed in the evaluation matrix. The score in the "Total Rank" column is the arithmetic sum of these three factors:
  - Application readiness for deployment,
  - Power system need,
  - Additional effort required to implement the application.

PMU Applications Prioritization Results

Application	Application Readiness for Deployment	XM system Need	Additional XM Effort to Implement	Total Rank
	Concept, In Development, Commercially available	High, Medium, low	Infrastructure, procurement, training	
Real-time Applications				
Frequency monitoring and control	3	6	3	12
Oscillation monitoring	3	6	3	12
Voltage stability monitoring	2	6	2	10
Advanced applications for system level phenomenon (includes SIPS and out of step protection)	2	6	1	9
Distributed State Estimation	2	6	1	9
Real Time Data Validation	2	6	1	9
Advanced Situational Awareness (ASA) (includes EMS and phasor management system)	1	6	1	8
Complex Event processing	1	6	1	8
Power flow monitoring	3	2	3	8
Local Control	1	4	1	6
Collaborative protection	1	2	1	4
Off-Line Applications				
Post-mortem Analysis	3	6	3	12
Model Calibration and Validation	2	6	2	10
Base-Lining	1	6	1	8
Synchrophasor system simulator	2	4	2	8
Operator Training Simulator	1	4	1	6
System separation/Islanding	1	2	1	4

PMU Applications Prioritization Results

- **First tier**: PMU applications ready to be implemented
  - Frequency monitoring and control
  - Oscillation monitoring
  - Voltage stability monitoring
  - Post-mortem analysis
  - Model calibration and validation
- **Second tier**: Applications that need further development
  - Advanced applications for system level phenomenon
  - Distributed state estimation
  - Real time data validation
  - Advanced situational awareness

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PMU Applications Prioritization Results

- **Second tier continued**: Applications that need further development
  - Complex event processing
  - Power flow monitoring
  - Base-lining
  - Synchrophasor system simulator.
- **Third tier**: Applications that need further R&D
  - Local control
  - Collaborative protection
  - Operator training simulator
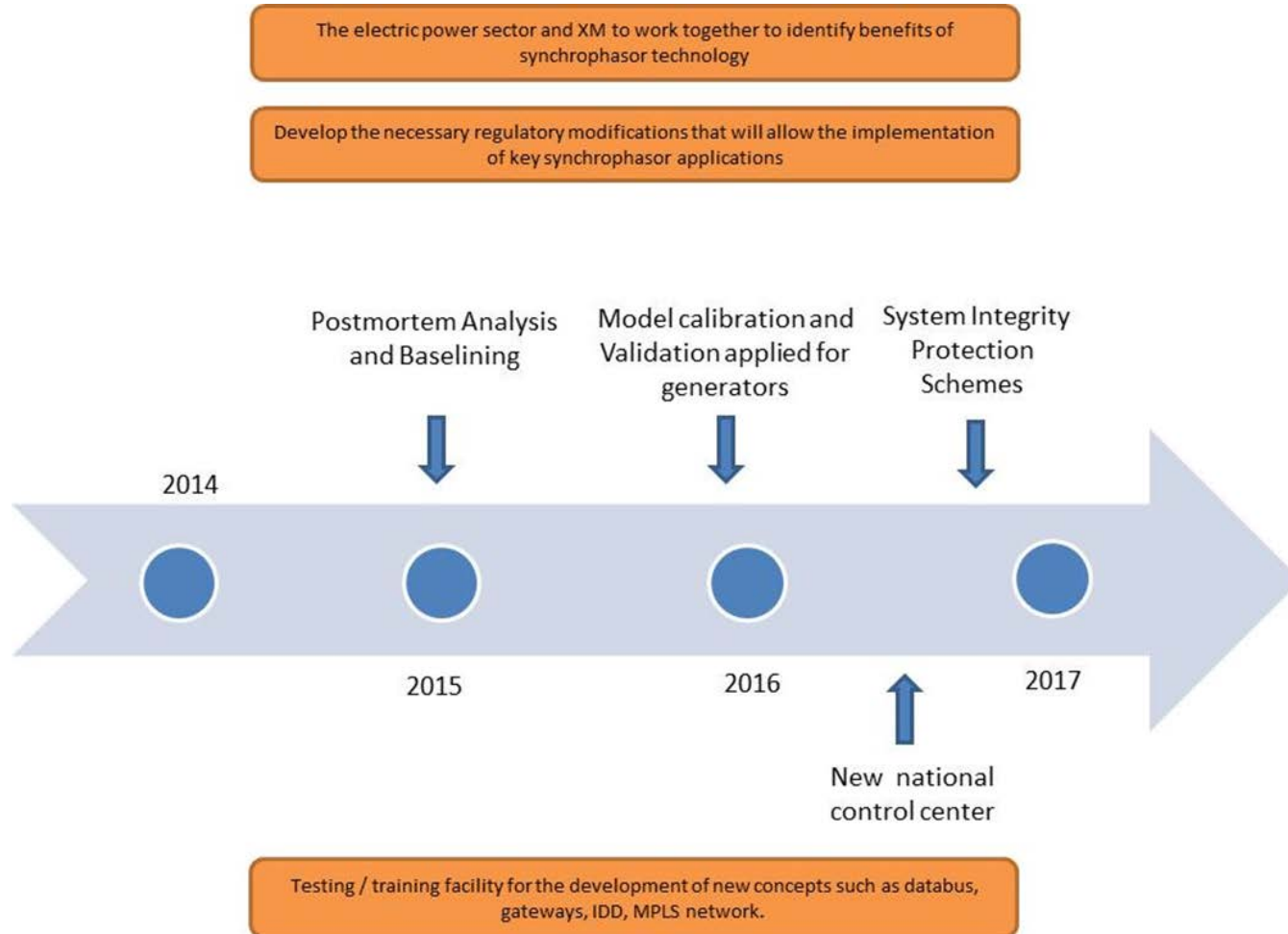 - System separation/islanding

Conclusions - Recommendation

- The following PMU-based applications were identified as and recommended for implementation in the first wave:
  - Frequency monitoring and control,
  - Oscillation monitoring,
  - Voltage stability monitoring,
  - Post-mortem analysis,
  - Model Calibration and Validation

XM Implementation Roadmap

The electric power sector and XM to work together to identify benefits of synchrophasor technology

Develop the necessary regulatory modifications that will allow the implementation of key synchrophasor applications

Postmortem Analysis and Baselining

Model calibration and Validation applied for generators

System Integrity Protection Schemes

2014

2015

2016

2017

New national control center

Testing / training facility for the development of new concepts such as databus, gateways, IDD, MPLS network.

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Thank You!

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