Easing the Integration of Emerging Energy Systems with the evolving needs of the Power Sector

Object Management Group

Industrial Internet Consortium – Technical Meeting

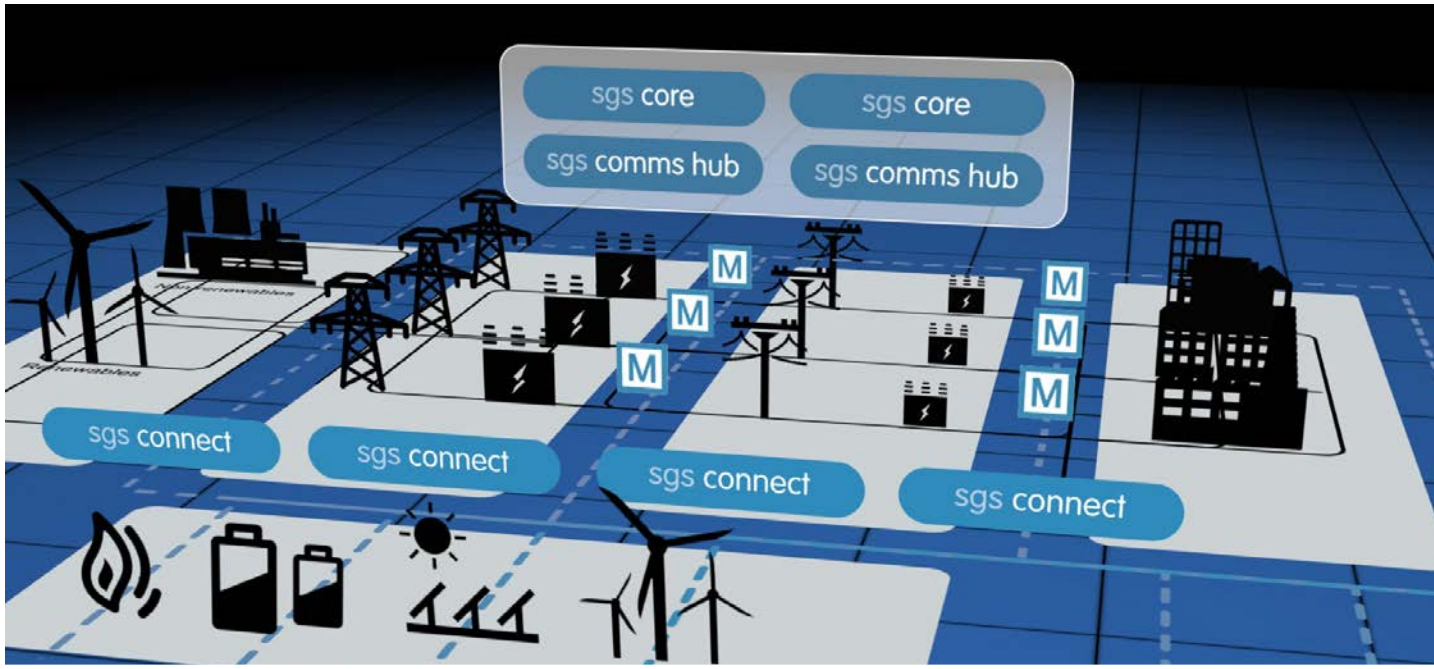
December 2015

Contents

- Company Background
- Case Studies
- Active Network Management
- Existing Platform
- Next Generation Platform
- Conclusions

Our story so far

- Established in 2008
- Spun-out of the University of Strathclyde
- 60 employees
- Launched US business in 2014



European activities:

- Deploying ANM platform technology to increase distribution grid hosting capacity with 4 of the 6 distribution utilities in the UK
- Participating in Regulatory change and UK Govt/Regulator Chaired working groups and forums
- Web Portals for online capacity assessment of new wind and solar interconnections

North American activities:

- Con Edison and Southern Company - Microgrids and Distributed Energy Resource integration
- PowerStream (Ontario) - non-wires alternatives
- NREL Demonstration Project
- REV Demo Project with Iberdrola in New York
- Participating in working groups: REV in New York, IEEE 1547 and IEEE 2030.7

What do we do?

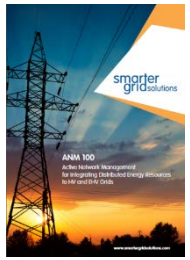
Project Lifecycle

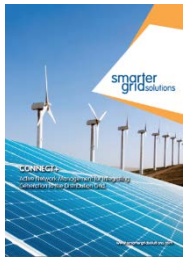
Consultancy, Analysis, Tools and Training

- Strategic Consultancy
- Power systems analysis
- ANM system design
- Online capacity analysis tool
- Desktop capacity analysis tool
- ANM planning and operational training

Products

Active Network Management





Systems Integration and Support

- Services to support the deployment of Active Network Management
- Ongoing support and maintenance of operational systems

UK Experience – 100MW connected by April 2015, further 250MW in the queue to connect through 2016

Orkney Isles - SSE

Delivered Benefits

- Operational since November 2009
- Connected 24 MW of new renewable generation capacity to 33 kV grid previously considered to be full
- 103% of electricity demand met by renewables in 2013
- Second phased involved integration of battery to reduce curtailment
- **Estimated saving of at least £30million**

Low Carbon London - UKPN

Delivered Benefits

- Successful trial of real-time event driven demand response platform and smart electric vehicle charging
- A third more distributed energy plants to export power to urban networks
- **£43m of savings identified through the visibility and contribution of Distributed Generation to security of supply.**

Flexible Plug and Play - UKPN

Delivered Benefits

- 9 generators (39 MW) accepted ANM connection offers out of the 24 connection offers made
- Reduction of CAPEX in connection offers of 75 – 95% to individual generators
- **Aggregate savings of £23.9m**

Skegness and Corby - WPD

Delivered Benefits

- Skegness: 5 offers accepted totalling 49 MW, further 14 offers issued totalling 45.5 MW.
- Corby: 2 offers accepted totalling 58 MW, further 7 offers issued totalling 80 MW.

North America Experience – Multiple feasibility studies, converting into technology deployments

Grid Integration: Microgrids and DER

Scope

- Engineering study to explore the challenges and opportunities
- Broad stakeholder engagement to develop recommendations for advanced control
- Time series analysis of secondary mesh and radial network to quantify grid hosting capacity
- Cost benefit analysis of advanced control

Microgrid Research & Development

Scope

- Microgrid Controller Use Case development
  - **Interconnected | Transitioning | Islanded**
- Time series analysis of 1 MW solar PV plus battery combination to maximize islanding duration and reduce interconnected peak demand
- Time series analysis of controlling solar PV to mitigate overvoltage

Asset Deferral Options

Scope

- Investigating the use of DER to defer substation upgrades
- Three case study options:
  - Battery Storage
  - Distributed Generation
  - Combination
- Locational benefits and losses assessment
- Cost benefit analysis

INTEGRATE

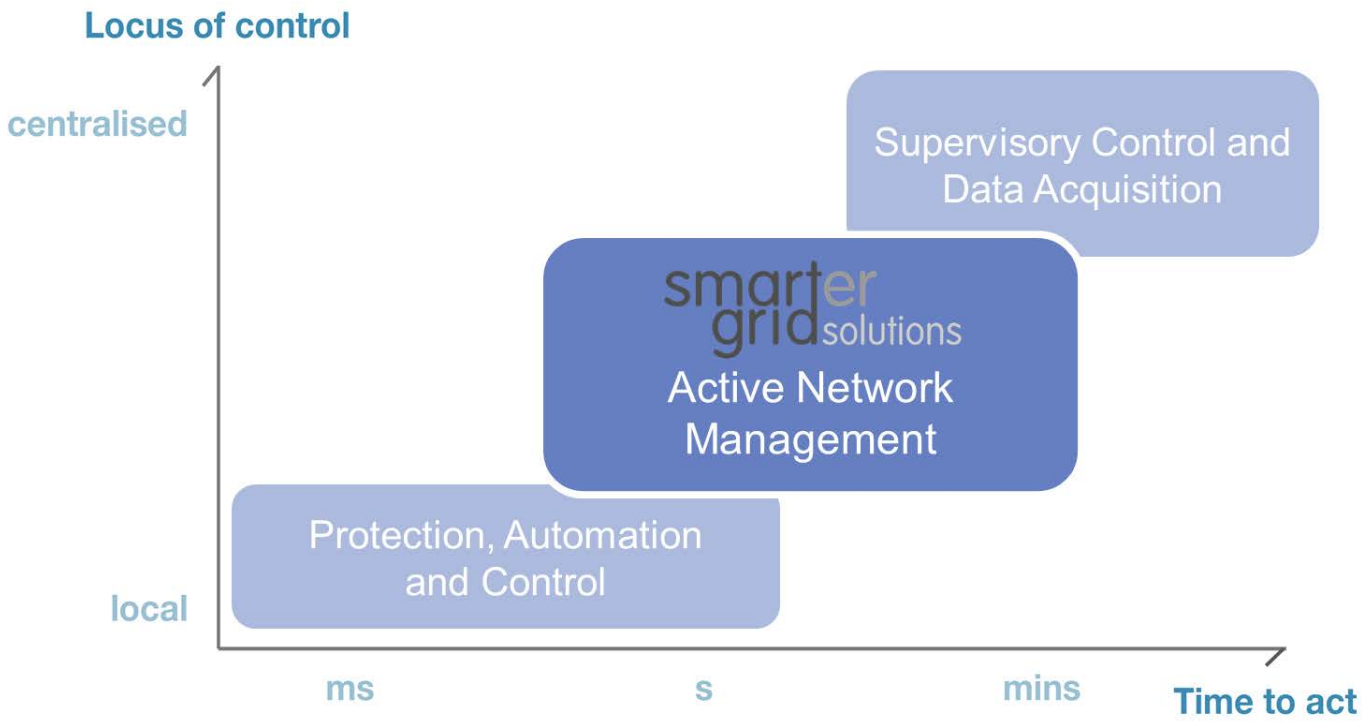
Investigate 3 Use Cases

- Smart Home
- Smart Campus
- Smart Distribution
- Deploy and test Smarter Grid Solutions technology using the NREL test network and real time simulator

Active Network Management

- Captures greater value from electricity distribution grids, improving return on investment and DER/customer satisfaction.
- Mission critical automation and control platform enables continuous operation of the grid closer to design limits, safely.
- Interfacing with grid edge devices it increases DER hosting capacity and enhances load relief programs.
- Configurable applications provide flexibility to adapt to regional differences: technical and business case.

Distributed, Autonomous, Real-time Control



- Distributed, end-to-end control system of **autonomous** control solutions for DER integration
- **Open standards** based integration upstream to EMS/DMS and downstream to field devices

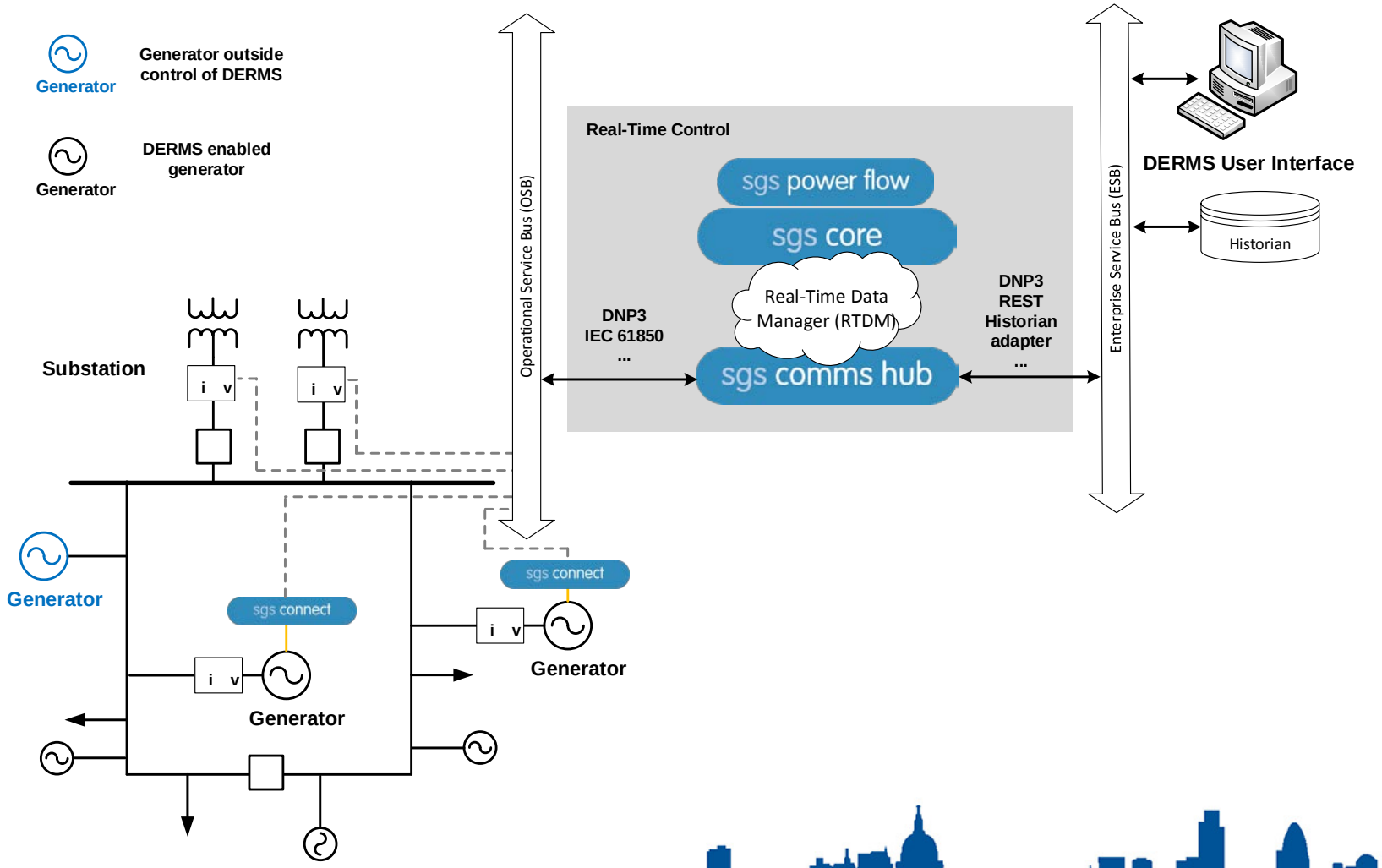
DER Integration Challenges – Data/Systems

- Where are we starting from?
  - In some cases only 50% of the distribution system is monitored
  - We need gradual investment in monitoring and communications
- Distribution is not transmission
  - What about bad data detection? Topology processing? Observability analysis? The state estimation problem at distribution is under-determined – pseudo data required
  - The above has implications for the techniques used to create visibility and perform pricing calculations
  - We need better models? But we also need to cope with a lot of changes…
  - Other power systems issues: e.g. imbalance, protection systems and losses
- Building out the control systems and enterprise systems
  - Centralized and decentralized approaches
  - Where to start?
  - Standards, cyber security

Many of the solutions to these challenges are in their infancy and being developed and tested in R&D activities

Existing ANM Platform

- Hub and spoke model
- Built for autonomous constraint management
- Suite of integration adapters & interfaces
- DDS as RTDM
- Extensively deployed – nearing 250 MW of DER under control



Technology Components

sgs core

Application host sharing a real time data with **sgs commshub**. Can execute on commodity servers with hot failover redundancy – or ruggedized hardware with no moving parts.

sgs comms hub

Gateway to field devices and externals systems; performing all data marshalling, conversion and processing for **sgs core.** Supports a focused range of industry protocols.

sgs connect

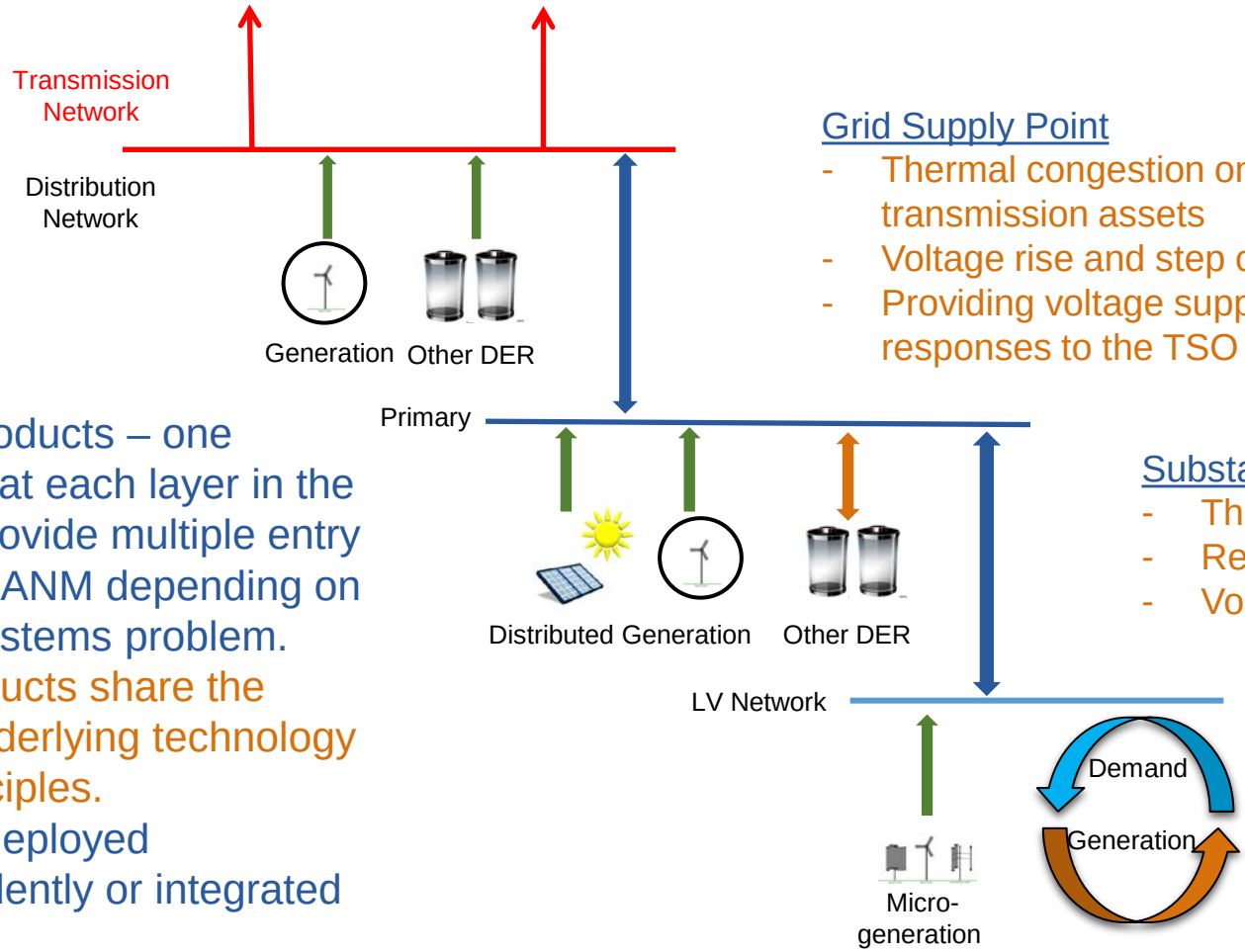
Field-level application host located at each controlled device providing an interface to and control of the grid edge device. Implements autonomous fail to safe mechanisms in the event of non-compliance, loss of communications or abnormal operation.

sgs power flow

Application package containing power flow algorithm and controlling logic for Thermal Constraint Management of network assets. Uniquely handles multiple network constraints with associated multiples of generators, including a varied generation mix and nested constraints.

Autonomous, deterministic operation guaranteed through engineering principles based on real-time design and trusted technology stack as utilised in complementary industries where critical plant-level control is required.

Typical DER challenges across the voltage levels

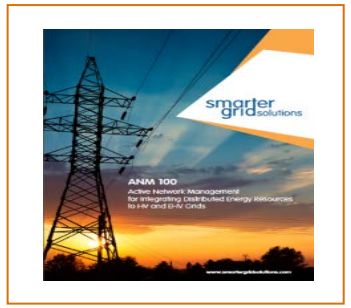


Grid Supply Point
- Thermal congestion on distribution or transmission assets
- Voltage rise and step change
- Providing voltage support and other responses to the TSO

Substation
- Thermal congestion
- Reverse power flows
- Voltage rise

Grid Edge / Device
- Voltage rise
- Site overplanting

- Three products – one targeted at each layer in the grid to provide multiple entry points to ANM depending on power systems problem.
- The products share the same underlying technology and principles.
- Can be deployed independently or integrated together.



Products

Application Status – Feature Pull from UK Clients

sgs powerflow - current

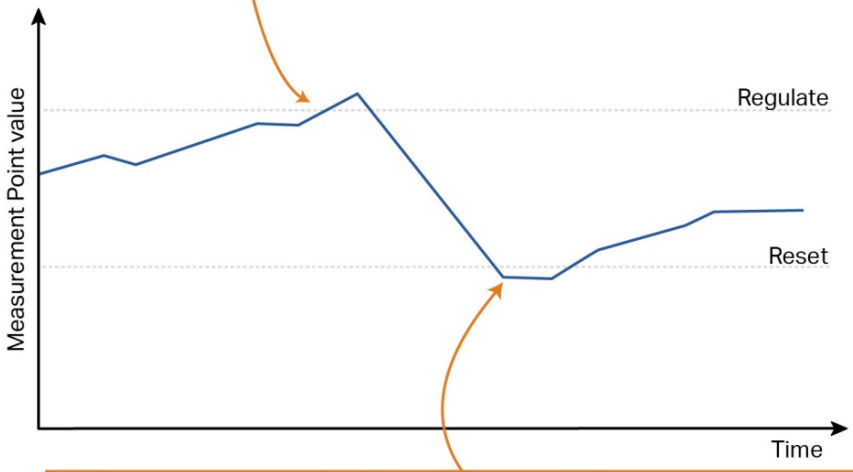
- Performance Validated for 250 Managed Objects
  - 100 Generators
  - 100 Circuit Breakers
  - 50 Meas Points
- Pre-canned Object Limit
- Real Power Control
- Shared/LIFO Principles of Access
- Multiple Controlled Device Types – WT/CHP/PV/ESS/CB

sgs powerflow – next stage

- Managed Object scaling increase 500/1000 mix of Generators/Measurement Points
- Multiple **sgs powerflow** instances (single instance/processor core)
- Dynamic Reconfiguration
- Network Topology Shift
- OSGi capable
- Federated Operation
- Arming
- Flexible Operating Margins
- Power Import/Export Zones

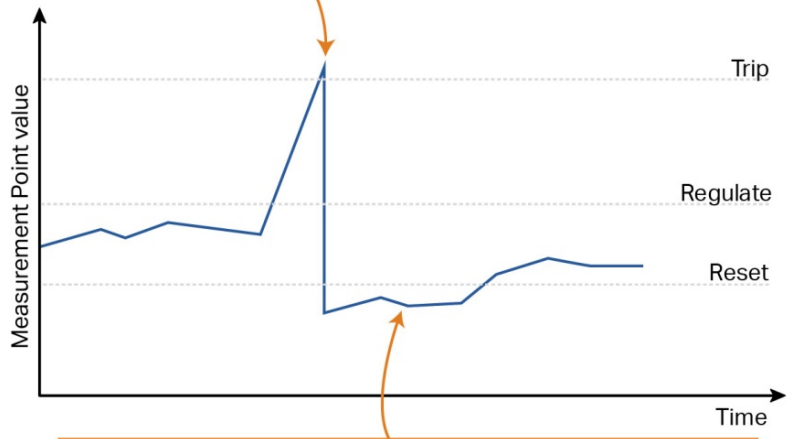
sgs PowerFlow - concept of operation (1)

Regulate threshold breached. Curtailment allocated to generators to target Measurement Point value < Reset.



Measurement Point value < Reset. CONNECT+ enters releasing mode. Releases generation to bring Measurement Point value between regulate and reset.

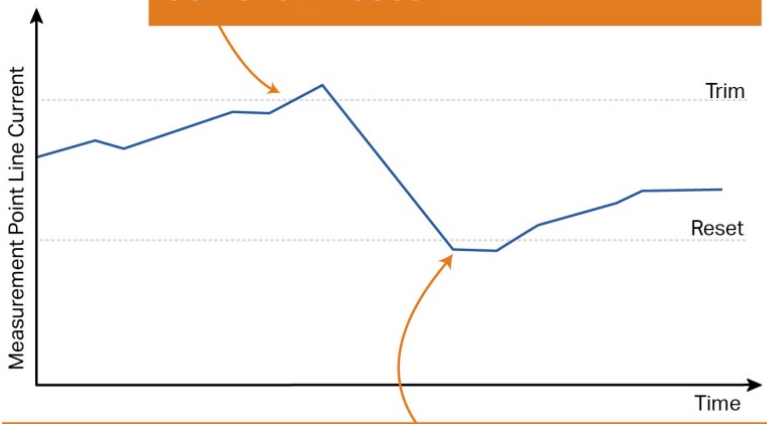
Trip threshold breached. ANM generator tripped.



Measurement Point value < Reset. Generator is re-closed and released.

sgs PowerFlow - concept of operation (2)

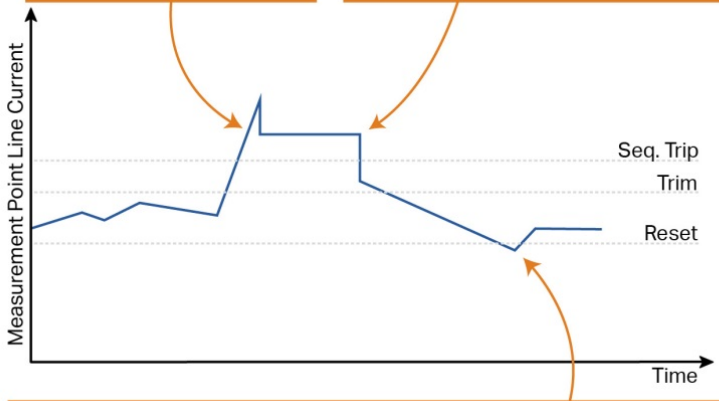
Trim threshold breached. Curtailment allocated to generators to target Measurement Point Line Current < Reset.



Measurement Point Line Current < Reset. **sgs power flow** enters releasing mode. Releases generation to bring Measurement Point Line Current between Trim and Reset.

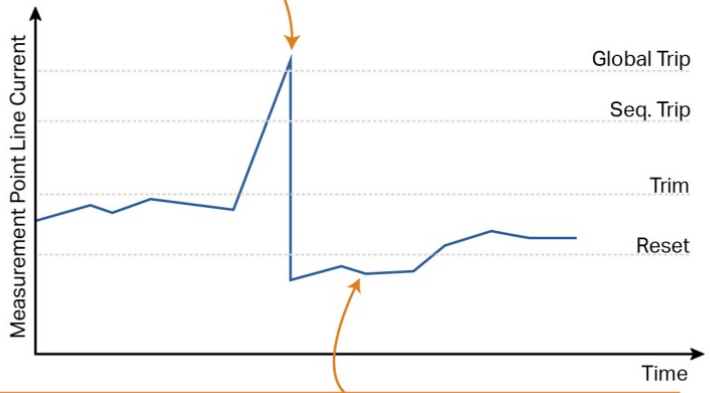
Sequential trip threshold breached. Lowest priority generator tripped.

Second lowest priority generator tripped. **sgs power flow** enters trim mode. Curtailment allocated to generators.

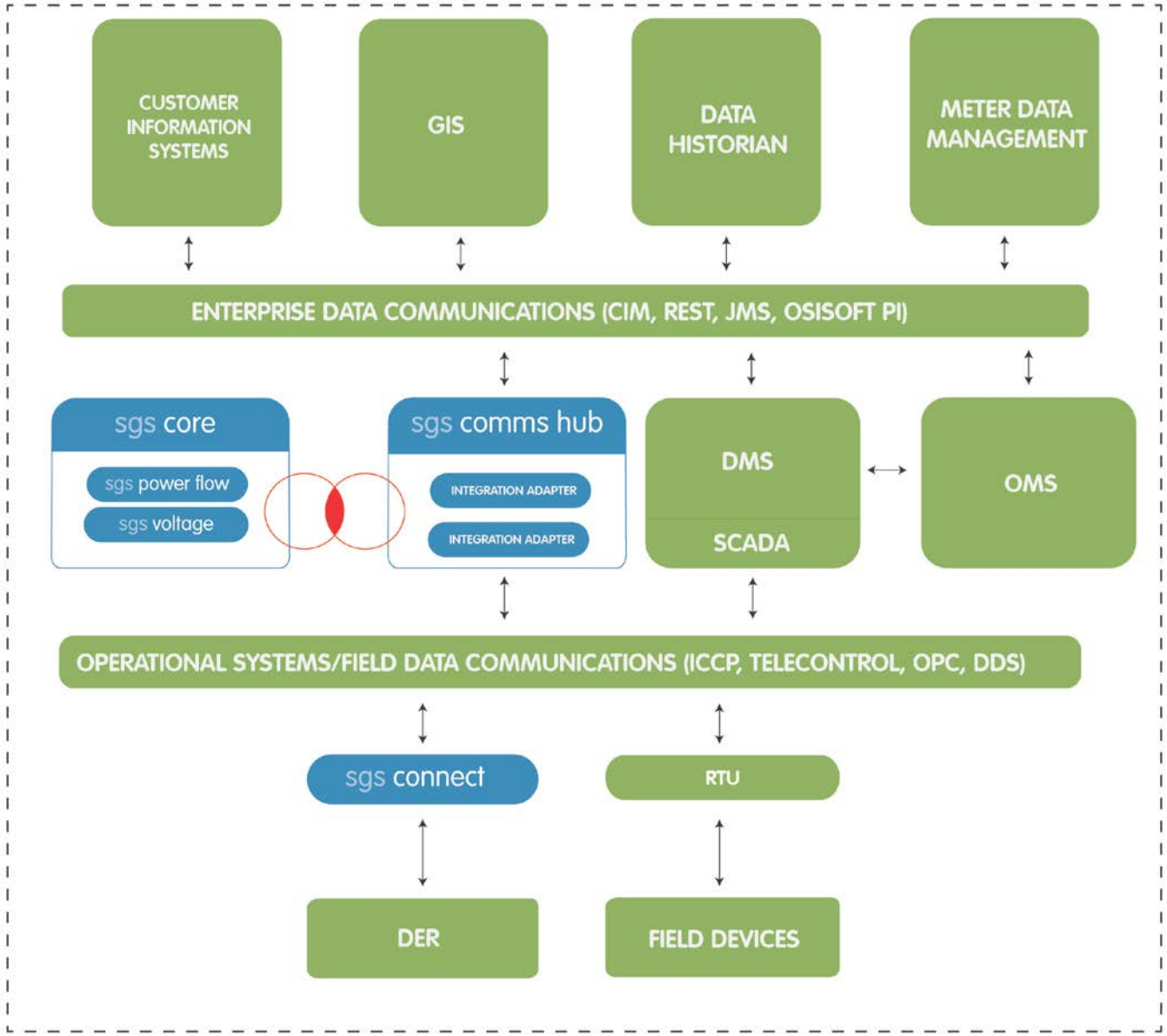


Measurement Point Line Current < Reset. **sgs power flow** enters releasing mode. Releases generation to bring Measurement Point Line Current between Trim and Reset.

Global Trip threshold breached. All ANM generators associated with measurement point tripped.

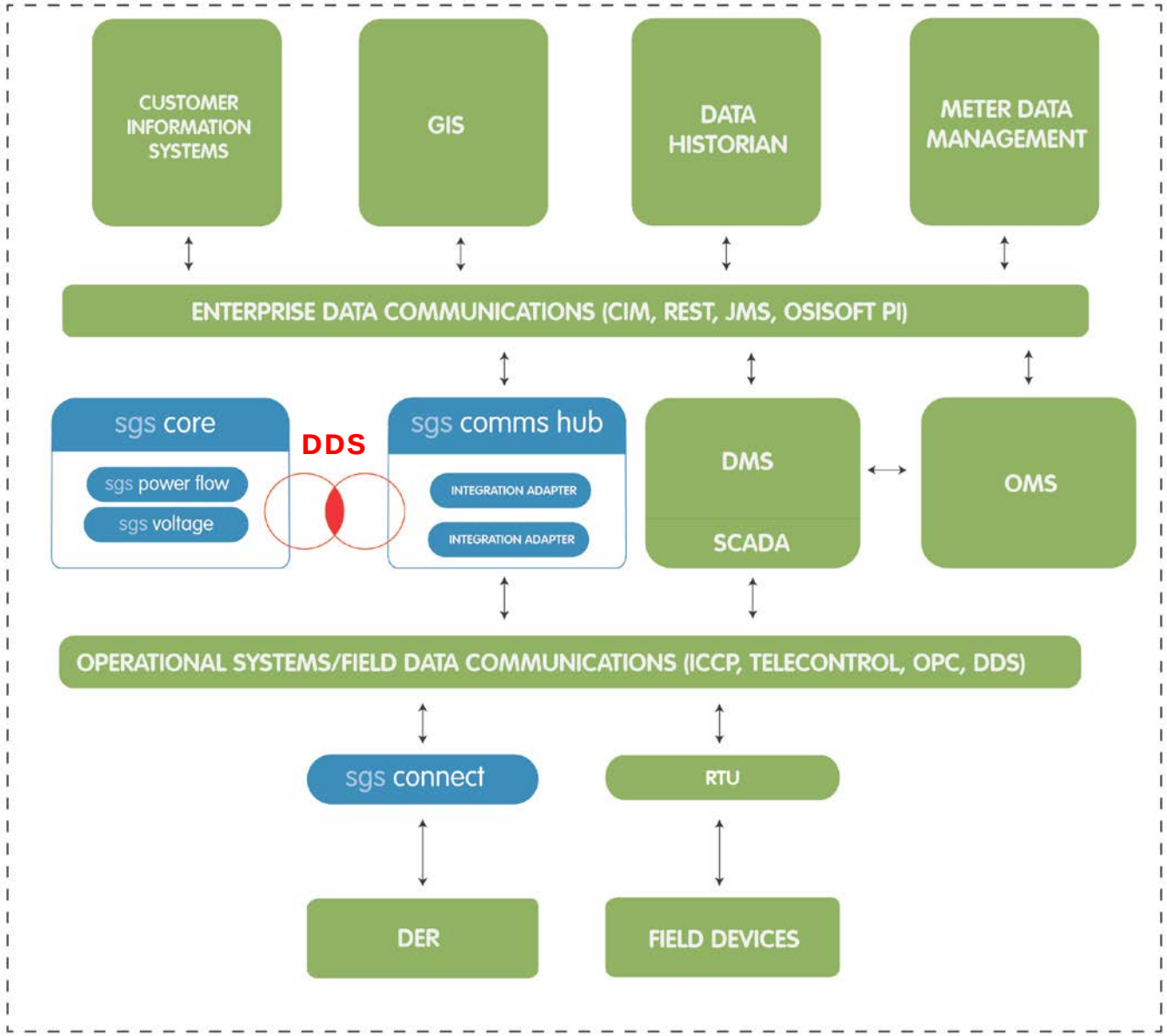


Measurement Point Line Current is below reset. Generators' circuit breakers are re-closed and generators released in priority order.



SGS Platform

Existing Integration Architecture



SGS Platform

Existing Integration Architecture

Current deployment options…

Hosting Options

- ANM hosts with hot failover/redundancy
- Server-grade computing infrastructure located in a Operational Telecoms environment
- Managing greatest number of ANM objects and MWs with telecontrol/data link to DMS
- Centralised management and support of deployed schemes

OR..

- ANM host with no redundancy
- Ruggedized server grade computing infrastructure located in substation/field environment
- Managing reduced number of objects and MWs with telecontrol/data link to DMS

Grid Edge / Device

- **sgs connect** dedicated to managing Generator Control and Circuit Breaker Control
- **sgs connect +** managing up to two constraints (one locally and one remotely) - normally generator site installation
- IP55 rated panel with **sgs connect** host supporting IEC61131 logic and upstream/downstream comms options

Constraints vs Control – Managing Complexity at Scale

- Distribution Active Network Management
- Large-scale Integration of Distributed Energy Resources
  - Solar
  - Wind
  - Batteries
  - CHP
  - Microgrids
- Typical Constraints affecting the Network
- Active Control of Power Flow
- Active Control of Voltage
- What about the locus of control?
- How can control be realised as autonomous?

DER Integration – Many Existing Telecoms Paths Limit Controllability

- Individual devices under Control
- Smaller networks of Controlled Devices operating autonomously
- Larger networks of Controlled Devices operating autonomously
- Media-agnostic Data Exchange Protocols
- Embedded Power System Algorithms
- Concept of ‘schemes’ allowing interaction between Active Objects

Field Data Management Challenges

- Sensor Data Acquisition
- Data Volume Considerations
- Limitations of Legacy Technologies
  - Serial Data Interfaces
  - Telemetered Data Polling
  - Conventional Tele-control
  - Report-by-Exception

Re-Engineering the Data Path

- Hub and Spoke
- Publish-Subscribe
- Deterministic Publish-Subscribe

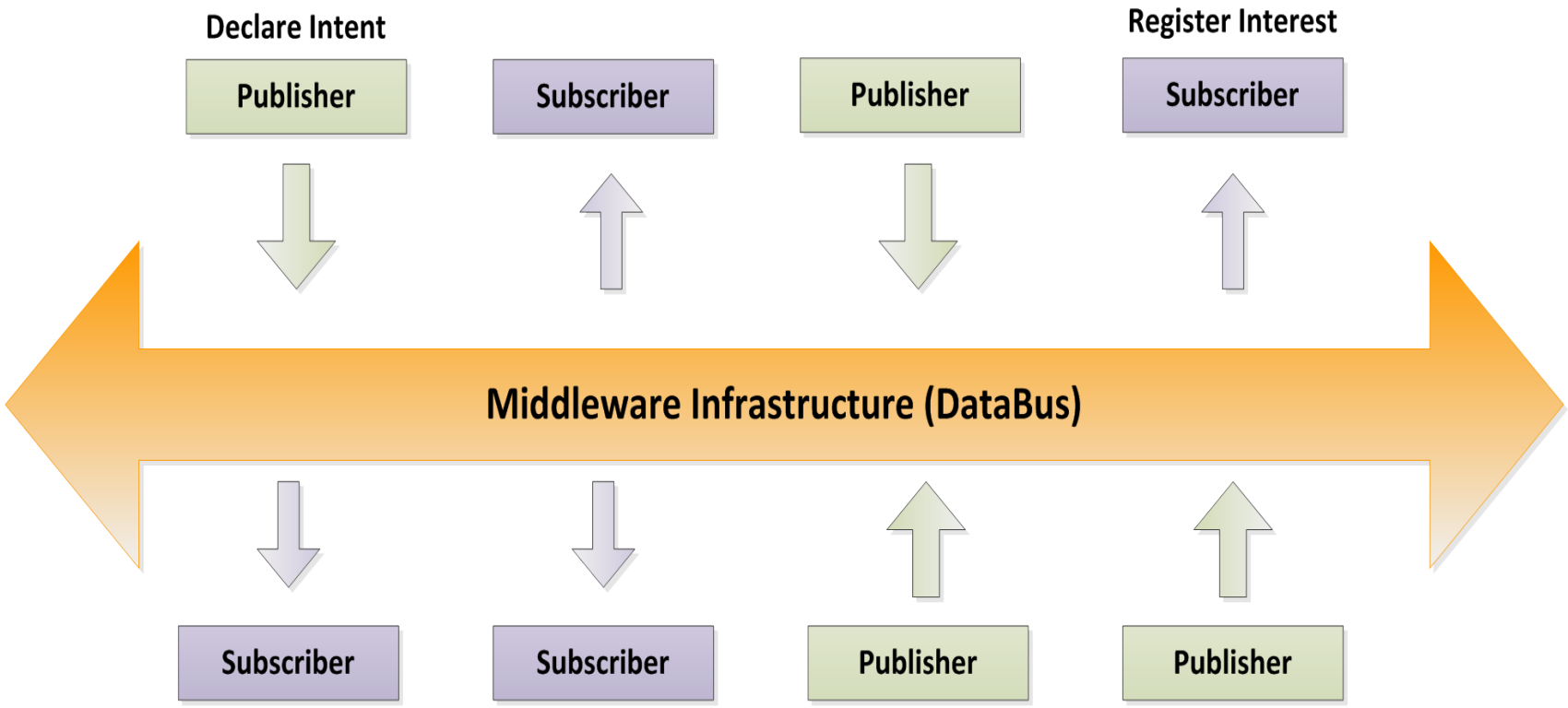
Controlled Devices - Fail To Safe

- Pre-determined localised Control Algorithms
- Backstop logic for graceful degradation
  - Communications failure
  - Device not responding
  - Failure of measured analogue or digital value

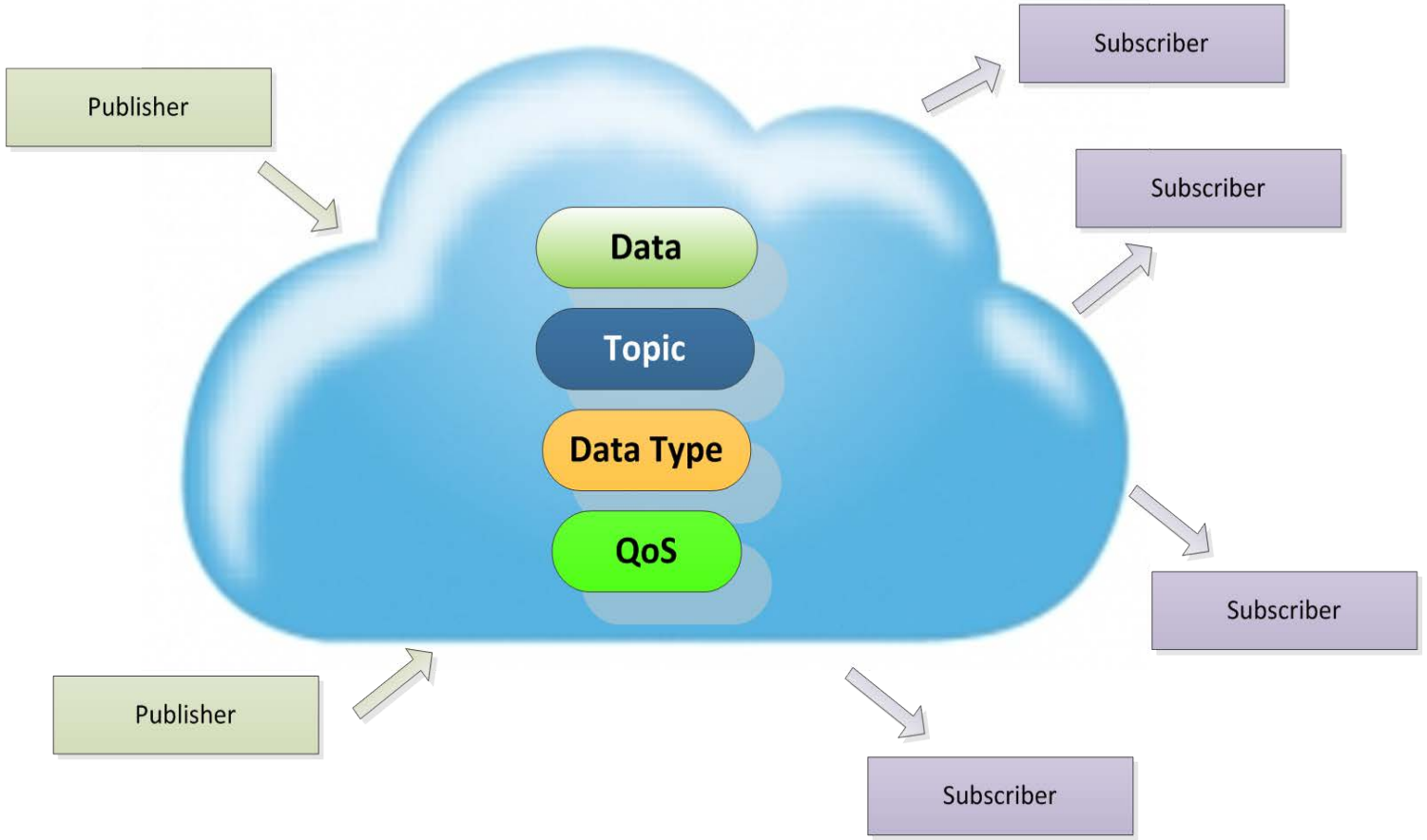
Hub and Spoke

- Dedicated linear connection to the data/controller hub
- Star Topology
- Enables Clustering of complex systems
- Remains the Model for Present Day ANM Deployment
- However, communication channel topology limits flexibility

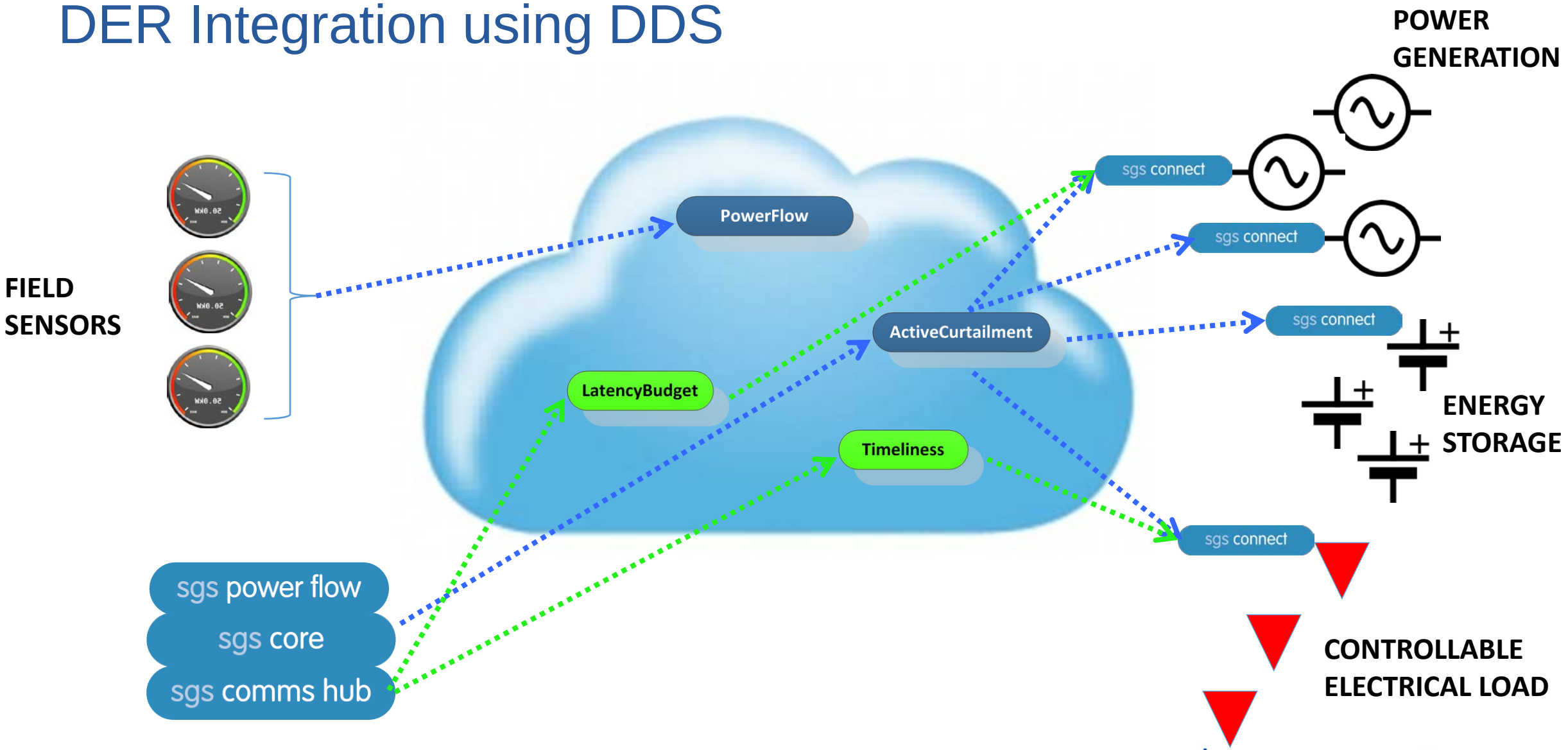
Publish-Subscribe



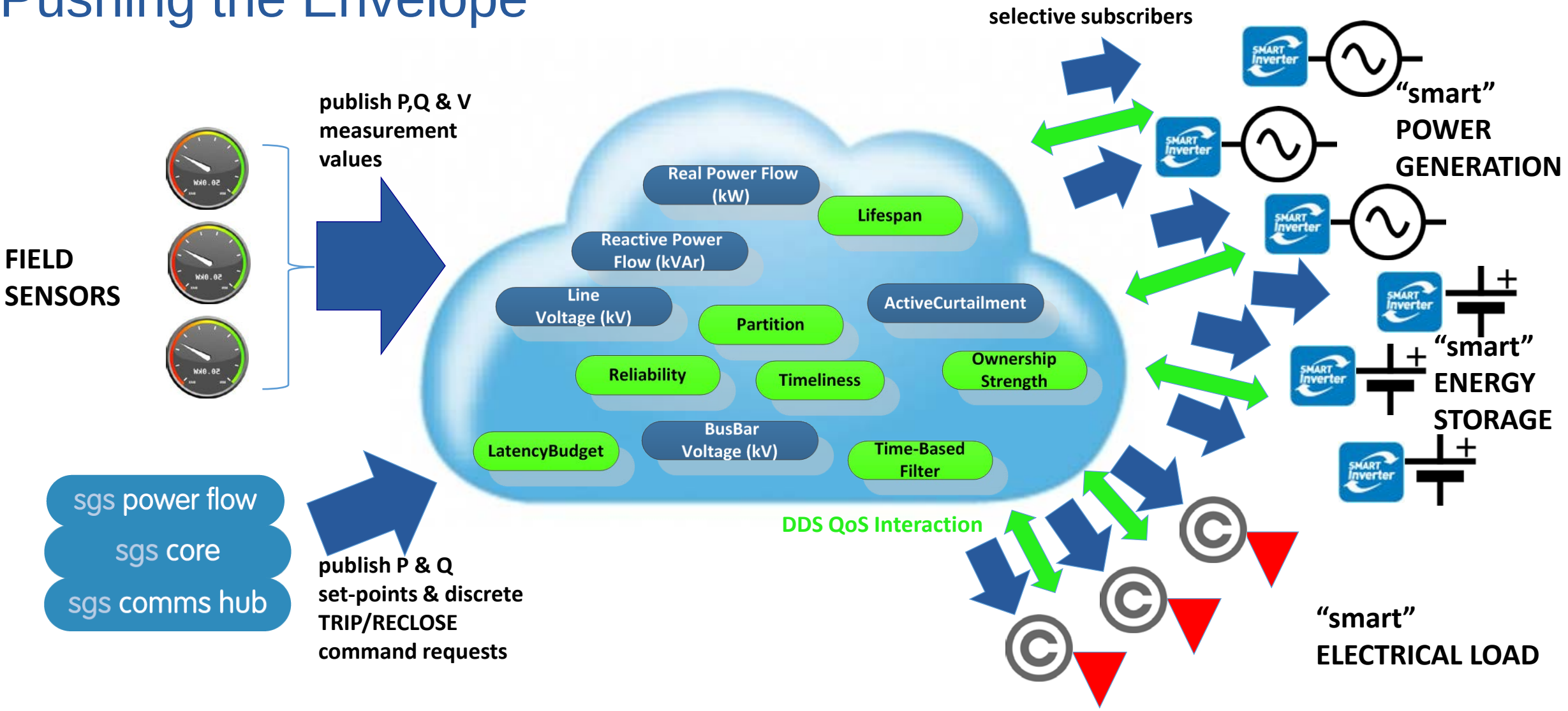
Deterministic Publish-Subscribe



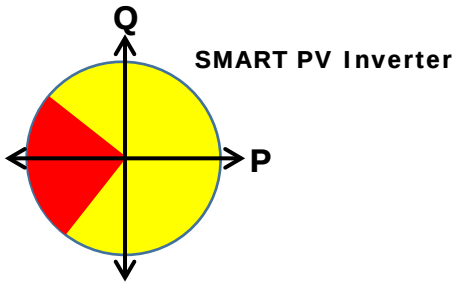
DER Integration using DDS

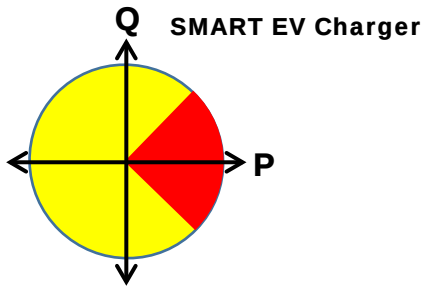


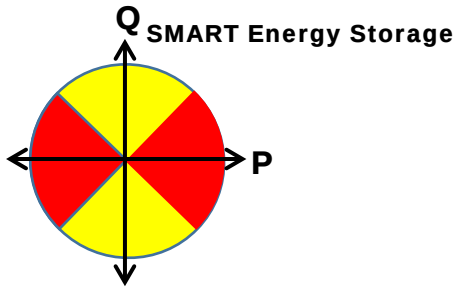
Pushing the Envelope

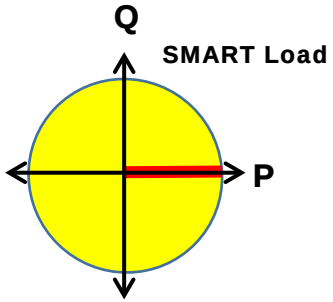


SMART Inverter Functions



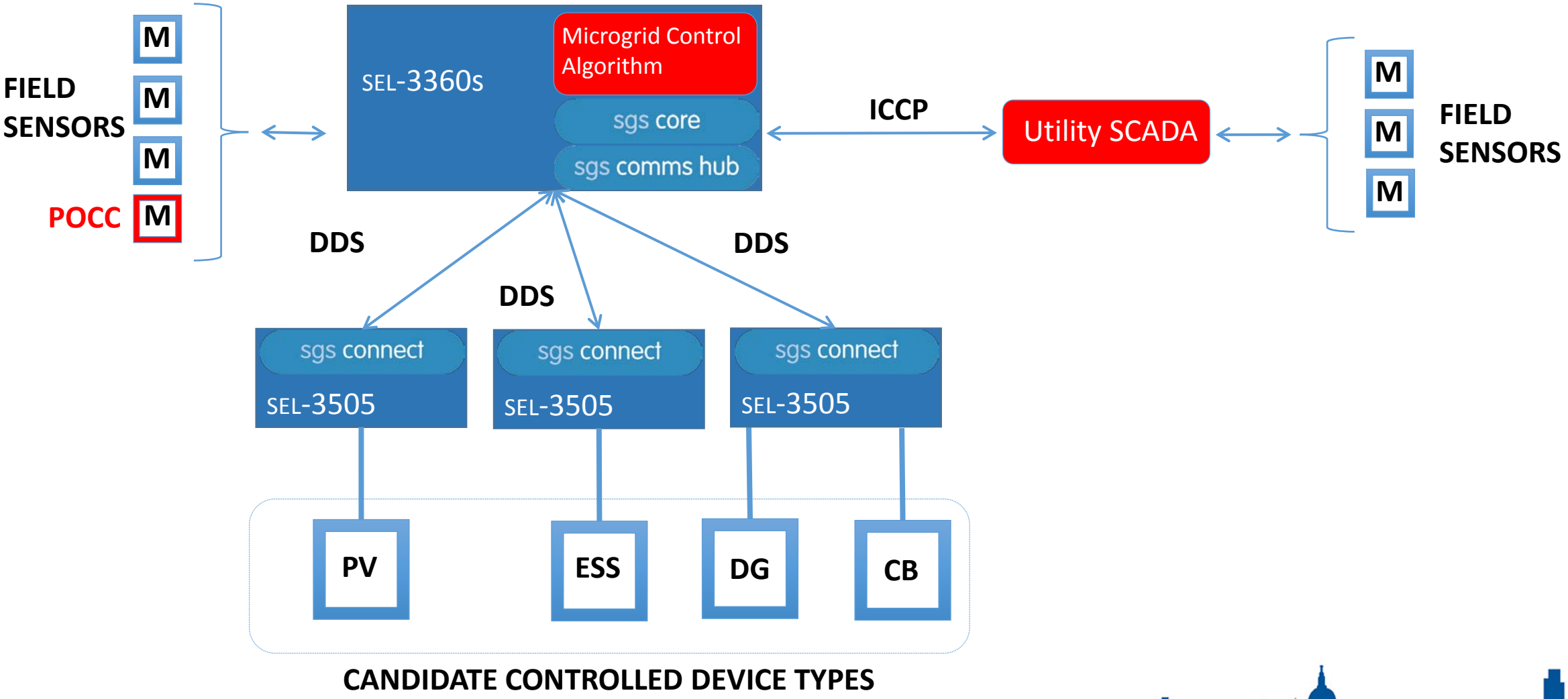






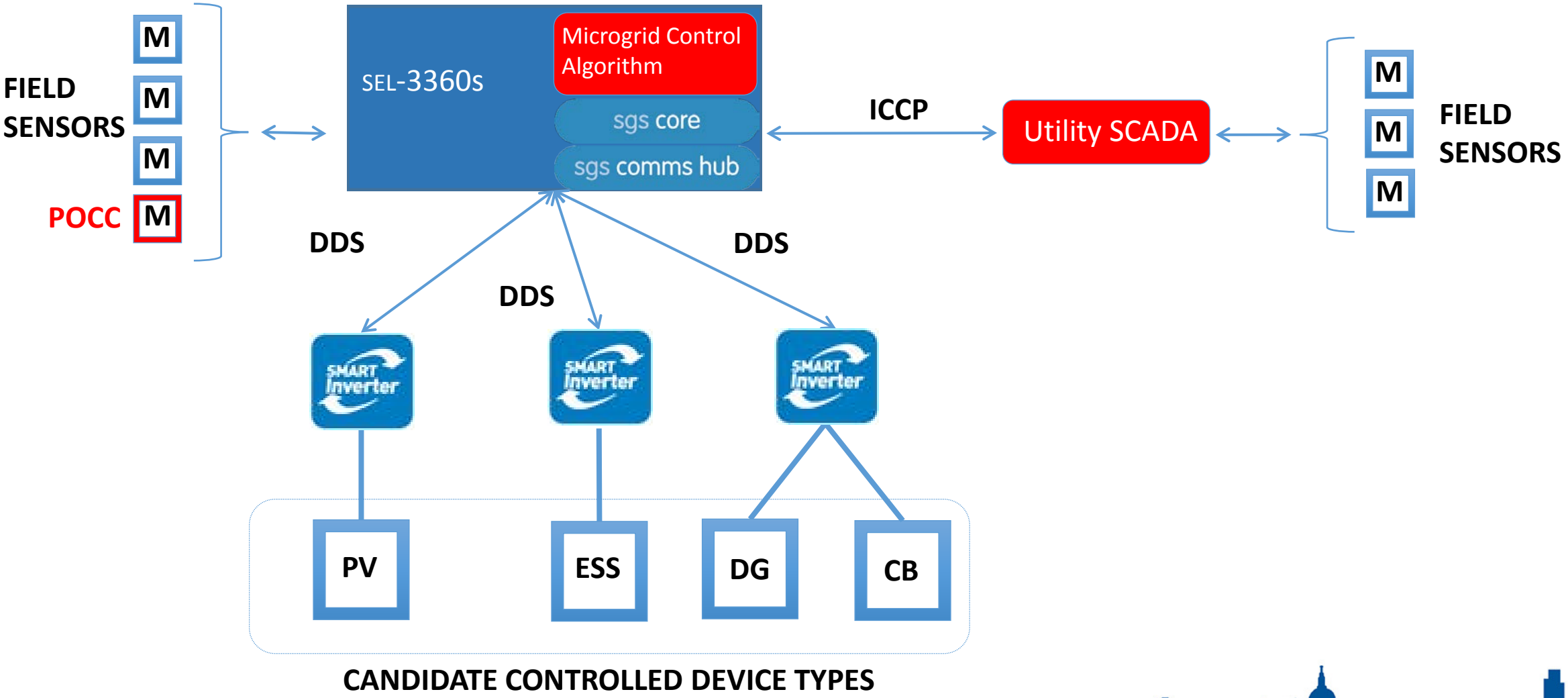
- Remote Connect/Disconnect
- Maximum Export Limits
- Ramp rates/Storage Capacity
- Fixed Power Factor
- Volt-Var [dQ/dV]
- Volt-Watt [dP/dV]
- Fast Volt-Var
- Fast Volt-Watt
- Watt-based Power factor Control
- Voltage Ride-Through
- Adjustable Power Factor

Planned Deployment Example



CANDIDATE CONTROLLED DEVICE TYPES

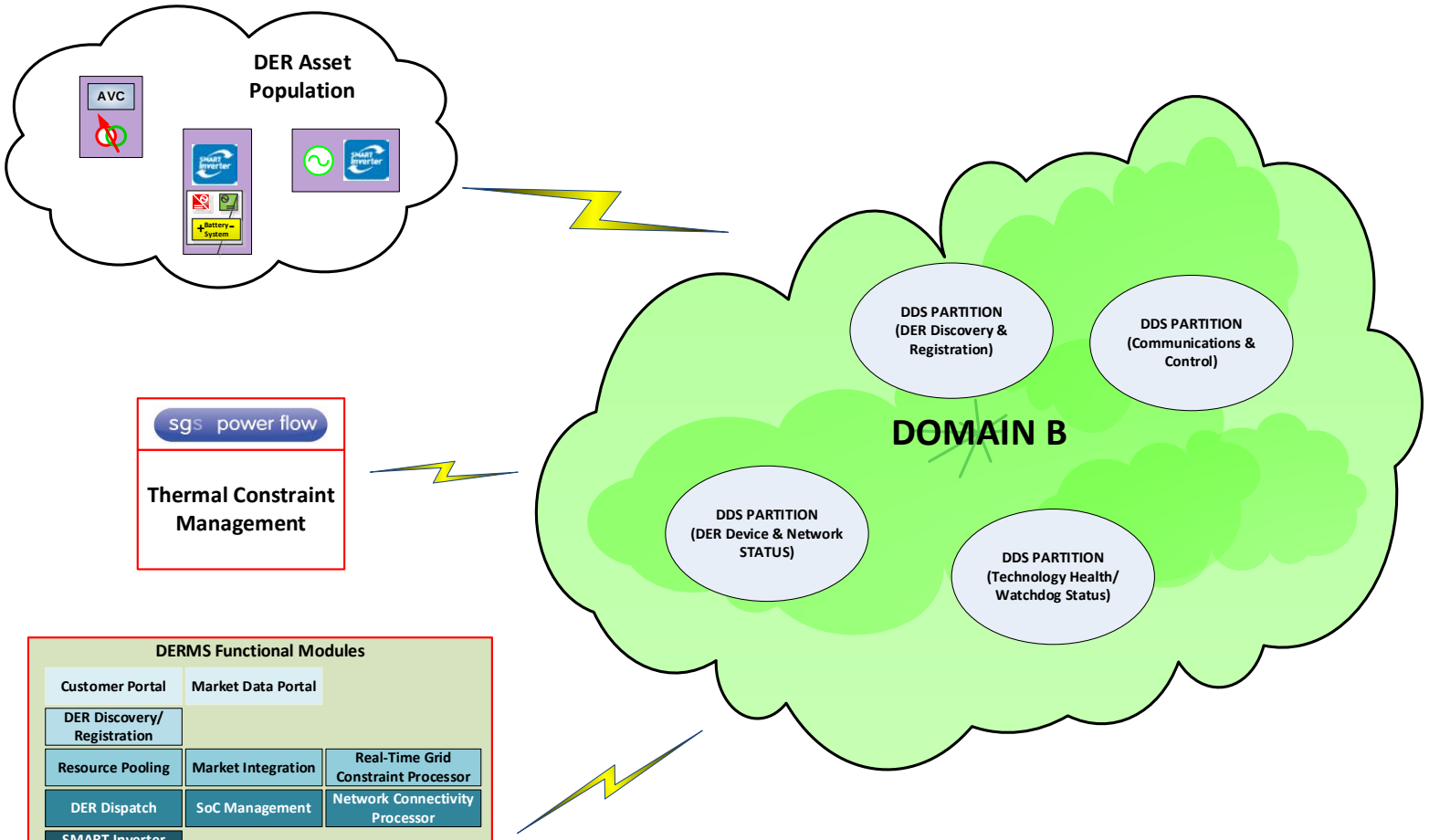
Deployment Evolution



Next Generation Platform - 2016

- Move beyond hub and spoke (i.e. local) to a dynamic and truly scalable distributed platform
  - Without sacrificing performance, security or impacting pre-existing systems and easing the on-boarding of new technologies, devices and 3rd parties
  - Federation and hierarchy to build “systems of systems” for incremental and dynamic addition of services required
- Leveraging a unique blend of technologies and architectural principles
  - Event-Driven Control
  - Leverage OSGI to assist with the notions of canonical object state, lifecycle and dynamic reconfiguration
  - Global Data Space – topic-based pub/sub utilizing DDS, co-existing multiplexed control and data planes
  - Quality of Service Management

Next Generation Platform - 2016



Next Generation Platform - 2016

- Common data standards and interfaces to operational and business systems across the utility landscape
- Streamlined on-boarding and discovery of devices
- User configurability
- Security
- Partitioning of Domains
- Dynamic/Extensible Data Model

- Stop/Start key processes in isolation
- Multi-instantiation of applications/services on a managed/as-needed basis with defined lifecycle
- Rich set of enterprise/device integration patterns
- Deploy and coordinate control capability at network zone/substation/feeder/customer layers
- 3rd party application integration and/or hosting (e.g. virtual load management/DER aggregators)

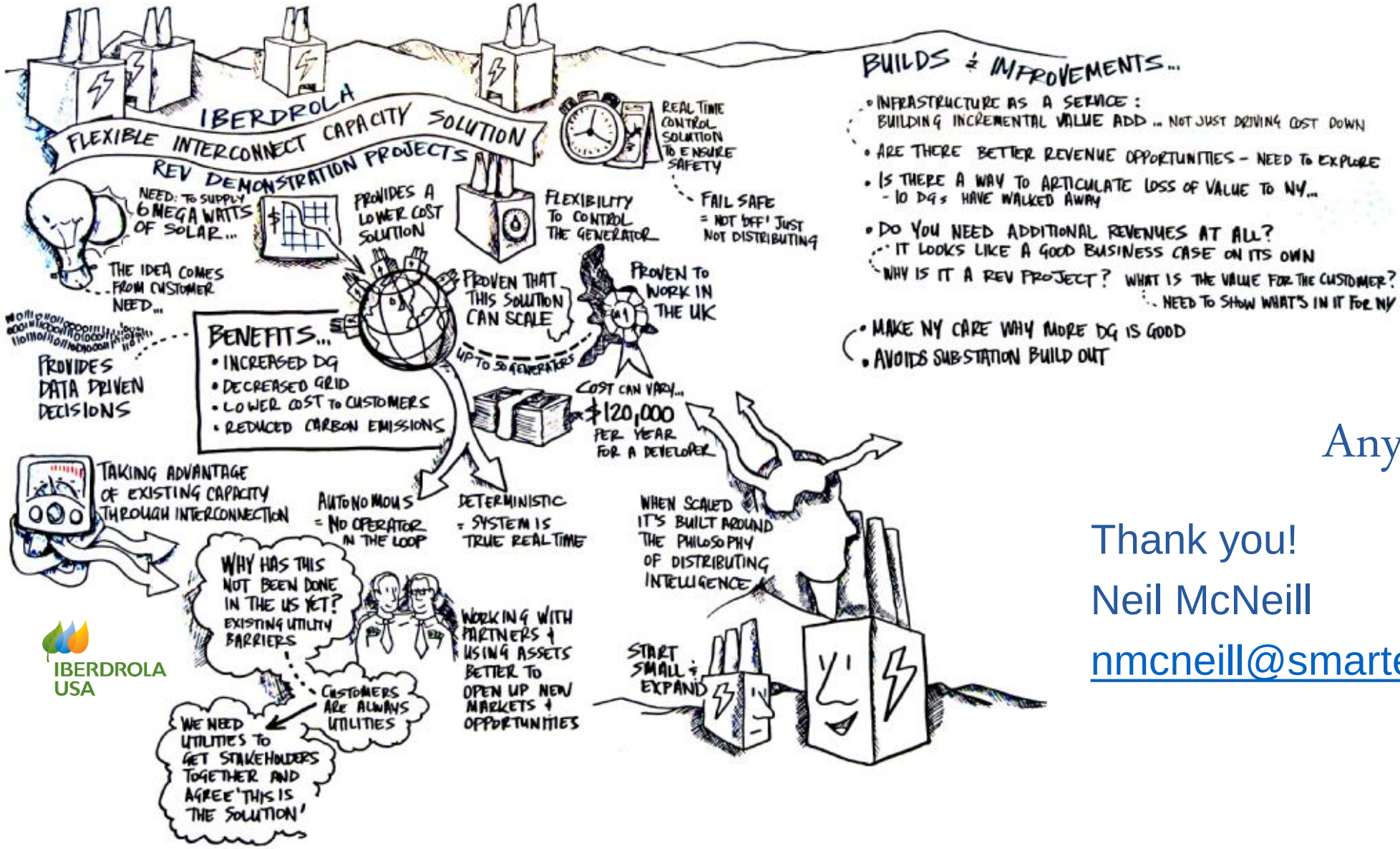
Solving the Dilemma

- Leverage technology advances from complementary industry sectors
- Proven for Critical National Infrastructure
- Data Distribution Service (DDS)
  - OMG supported
  - Tuning for existing/future telecommunications infrastructure
  - Configure for Target Domains – Smart Grid/ANM/DER Integration

- Move to standard API
- Robust Quality of Service Model
  - Controls actual data-level communications
  - Manage Data Network Bandwidth
  - Manage System Resources across Data Network
  - Manage Data Object Persistence, Timeliness and Reliability
- …Results in adaptive Active Network Management across disparate Telecommunications Infrastructures

Conclusions

- We have proven our approach and technology
  - Not too new or small to be ‘risky’ but small enough to be flexible and agile – we have proven ourselves as partners time and time again
- We are delivering early North American projects using technology that …….
- Our next generation platform aligns with many of the challenges and opportunities facing …..
- We will be opening an office in California in 2016
- We’d



Source: AT Kearney / 8works

Any questions?

Thank you!

Neil McNeill

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