Energy Research and Development Division
FINAL PROJECT REPORT

DISTRIBUTION SYSTEM FIELD STUDY WITH CALIFORNIA UTILITIES TO ASSESS CAPACITY FOR RENEWABLES AND ELECTRIC VEHICLES

Appendix A

Prepared for: California Energy Commission
Prepared by: The Regents of the University of California - California Institute for Energy and Environment

MARCH 2015
CEC-500-2015-058-AP

APPENDIX A:
Presentations from Sept. 5, 2014 Distribution Monitoring Workshop

Development of an Advanced Distribution Monitoring Plan

presented at:

Distribution Monitoring for Renewables Integration (DMRI) Project Workshop

Berkeley, CA

September 5, 2014

by:

The Electric Grid Research Team

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Disclaimer

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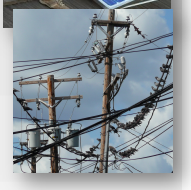
DMRI Project Background



1. Governor Brown's Clean Energy Jobs Plan (2011): 12,000 MW of distributed - mostly renewable - generation
2. How will CA electric distribution systems behave with 12,000 MW of DG?
3. Need additional monitoring and measurements to answer the question.
4. CIEE selected by CEC to develop a plan to characterize CA electric distribution system, i.e., the Distribution Monitoring for Renewable Integration (DMRI) Project

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DMRI AMP Project in a Nutshell

- **1st Task: Use data from existing utility monitoring efforts to learn what is being measured and what isn't.**
- **2nd Task: Design an "intentional" monitoring plan to characterize the electric distribution system with high renewables penetrations, and answer questions about what is happening, and might happen.**

The DMRI Advanced Monitoring Plan (AMP)

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DMRI AMP:

What are we going to see?

Illustration: Michael Sowa

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Workshop Purpose and Outcome

Purpose: To further articulate and refine an intentional Advanced Monitoring Plan designed to

- close any gaps in the ongoing monitoring efforts being done individually by utilities, and
- explore the unknown
- for high-penetration renewables and other distributed energy resources.

Outcome: Participants' critical review, comments, and amendments

- regarding a "straw man" plan, used as a starting point for this workshop,
- will be reflected in a plan to be submitted to the California Energy Commission by CIEE under Contract 500-11-019.

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Workshop Agenda

10:00 am	Welcome, Introduction and Background (Merwin Brown, CIEE)
10:20 am	DMRI: Technical Concerns and Monitoring Efforts (Sascha von Meier, CIEE)
10:40 am	Lessons Learned from Existing Data (Reza Arghandeh, CIEE)
11:00 am	Results of DMRI Survey: Distribution Monitoring Needs (Lloyd Cibulka, CIEE) Short Break
11:30 am	'Straw Man' Advanced Monitoring Plan (Bob Russ, Consultant)
12:30 pm	Working Lunch (provided)
1:30 pm	Facilitated Discussion of the Straw Man Plan (Merwin Brown, CIEE) Short Break
3:00 pm	Beyond the DMRI Project: Fulfilling the Plan (Merwin Brown, CIEE)
3:45 pm	Conclusion and Next Steps (Sascha von Meier, CIEE)
4:00 pm	Adjourn

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Distribution Monitoring and Renewable Integration: Technical Concerns that Motivate Monitoring Efforts

presented at:

Distribution Monitoring for Renewables Integration (DMRI) Project Workshop

Berkeley, CA

September 5, 2014

by:

Sascha von Meier

Electric Grid Research Team

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Desired Benefits of Distribution Monitoring Research

- Safe and reliable distribution system operation
- Visibility for transmission and system operators beyond the substation
- Informing DER specifications and interconnection standards for safety, efficiency and economics
- Informing needs for strategic infrastructure upgrades

All of the above depend on good data.

Exploratory research vs. specific applications

Data for specific applications:
should support characterization of use-case problem
provide actionable intelligence
effort & cost commensurate with problem to be solved

Data for exploratory research:
should establish empirical baseline, reference for future data
reveal appropriate data resolution
reveal any important, previously unknown phenomena
allow some generalization

Benefits of an Exploratory Approach

- Identify previously unknown phenomena
- Provide a baseline for comparisons of feeder behaviors at different DG penetration levels
- Provide empirical knowledge to inform follow-on research design
- Provide empirical data for early analytical model modifications, developments and/or validations
- Reduce mistakes that could result from incorrect assumptions about system behavior due to lack of empirical data

Questions

- What lessons can we learn from empirical feeder data toward the most successful integration of distributed energy resources?
- What generalizations or extrapolations can be made from a subset of studied feeders to broader categories of distribution feeders?
- What benefit is there to a collaborative approach among California utilities, as opposed to individual studies?

Some distribution feeder attributes:

- underground vs. overhead
- voltage level
- topology (e.g. radial, loop, network), sectionalizing options
- circuit length, load density
- load characteristics (time profile, load factor, predictability)
- anticipated load growth, EV, DG
- sensitivity of loads to power quality
- phase imbalance
- extent of SCADA capabilities in place
- type of voltage regulation equipment
- type of protective equipment and protection scheme
- exposure to environmental insults

Possible technical issues on distribution circuits with increasingly active components:

- Capacity limitations (transformer overload)
- Reverse power flows
- Protection coordination problems (relay desensitization)
- Undesirable voltage profiles (range violation, inverted profile)
- Rapid voltage variations (excessive tap changes, premature wear)
- Harmonics (excessive losses, impact on sensitive loads)
- Phase imbalance (excessive losses, nuisance trips)
- Unintentional islanding possibility
- Collective behavior of inverters (cascading disconnect)
- Impact of advanced inverter functions (LVRT, LFRT, Volt-VAR support)
- Visibility to transmission level/ISO (vulnerability to fast ramps)
- “Sharks” (oscillations, unknowns)

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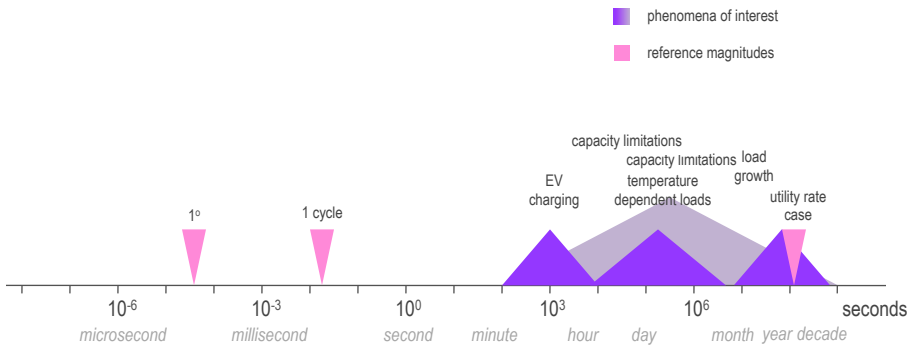
Issues on a Time Scale



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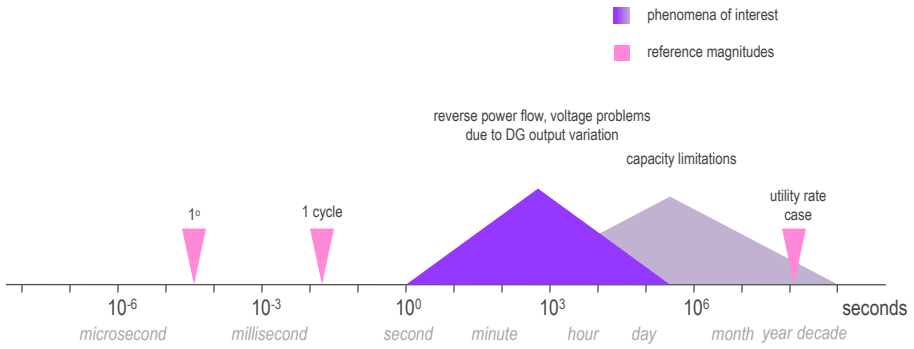
Issues on a Time Scale



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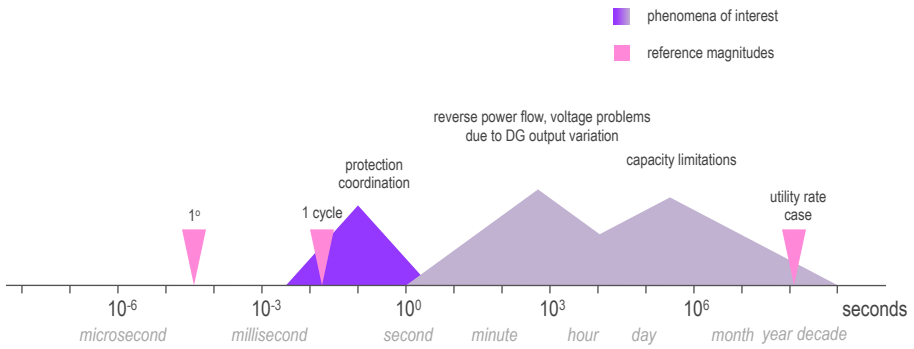

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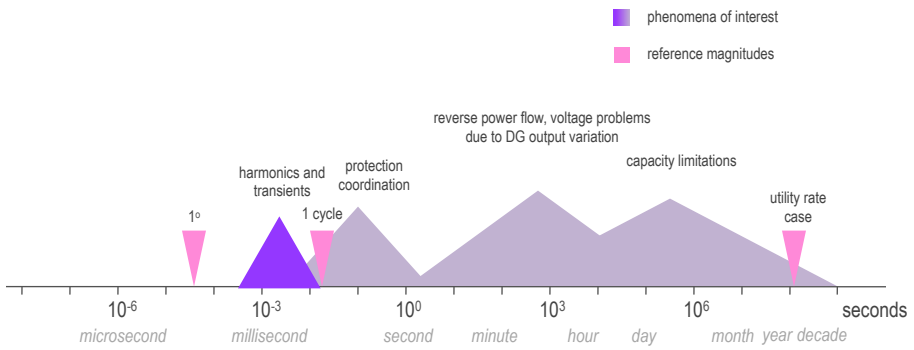

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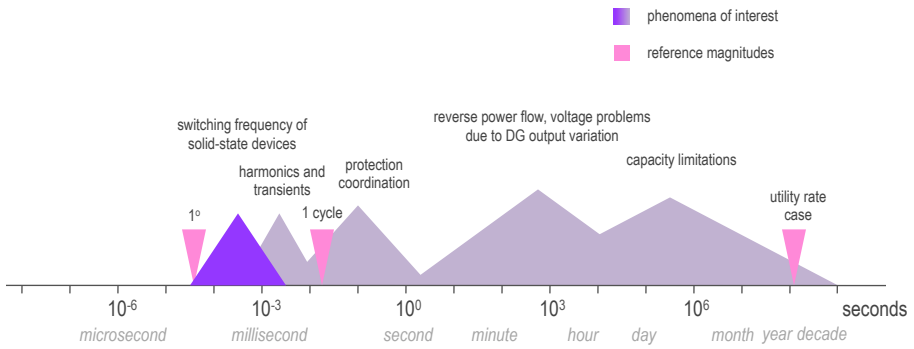
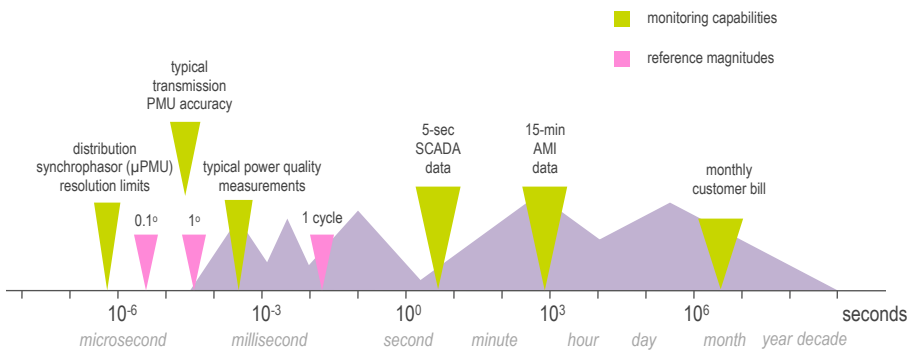
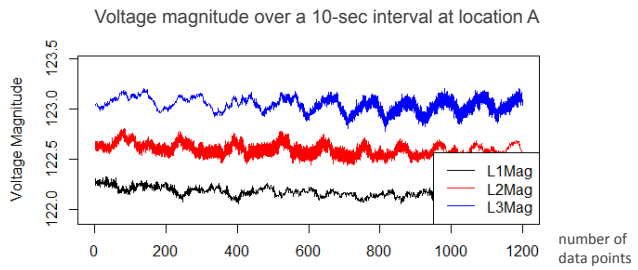
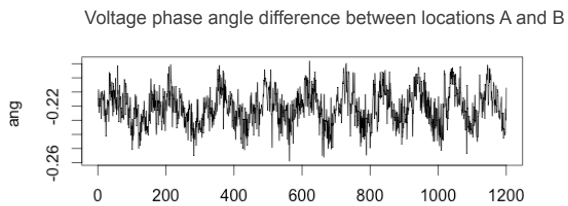


Monitoring Capabilities on a Time Scale

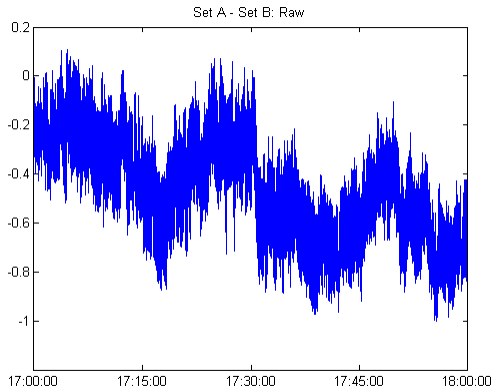


Sample illustration of high-resolution data: Low-frequency periodic behavior observed with µPMUs





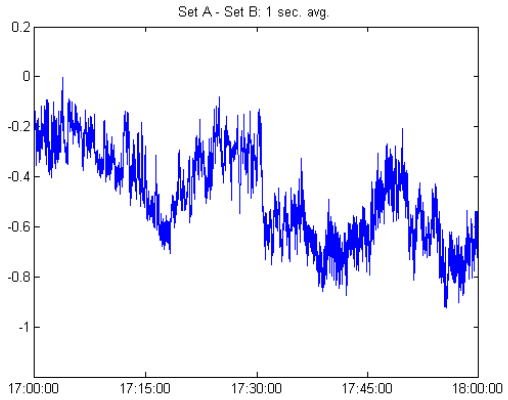
Sample Illustration of high-resolution µPMU data



no filter

Voltage phase angle difference between residential locations in El Cerrito and Oakland on July 9, 2014 5-6 pm PDT

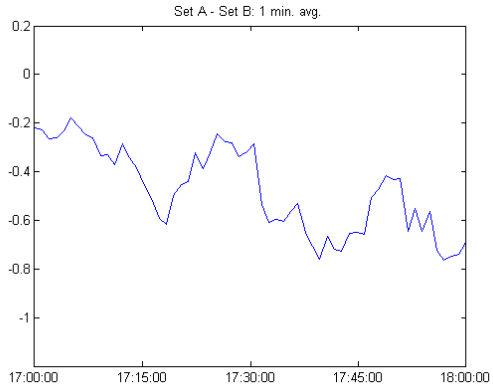
Sample Illustration of high-resolution µPMU data



one-second sliding average

Voltage phase angle difference between residential locations in El Cerrito and Oakland on July 9, 2014 5-6 pm PDT

Sample Illustration of high-resolution µPMU data



one-minute sliding average

Voltage phase angle difference between residential locations in El Cerrito and Oakland on July 9, 2014 5-6 pm PDT

Characterization of Distribution SCADA Data
Some Lessons Learned

presented at:

Distribution Monitoring for Renewables Integration (DMRI) Project Workshop

Berkeley, CA

September 5, 2014

by:

Reza Arghandeh

Electric Grid Research Team

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Outline

Challenges in SCADA Systems

"Bad Data"

Filling the gap with Advanced Monitoring

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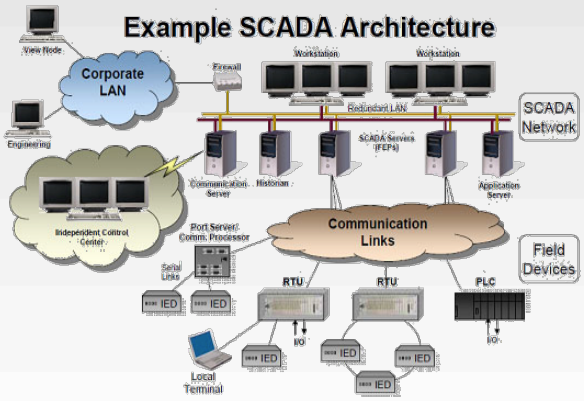
Challenges in SCADA Systems: Architecture Level

- Hardware
- Network Arch
- Software
- Integration



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Challenges in SCADA Systems: Enterprise Level

Lack of observability downstream the substation	Observability
Lack of updated and accurate distribution network model	Network Model
Lack of quick and easy access to the data for different parts of the organization	Data Access
Lack of unified data format for different applications and different software packages	Data Format
Concerns regarding data security	Sys Integration
Concerns regarding scaling up to the big data era	Security
	Big Data

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Challenges in SCADA Systems: Field Level

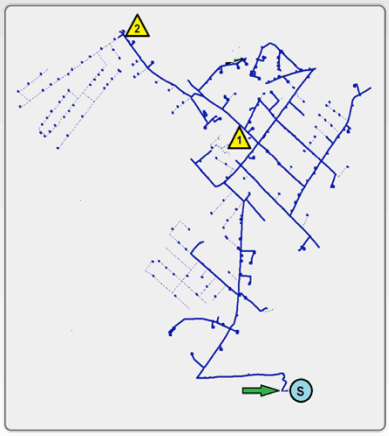
SCADA is mostly installed in substations

DG, Inverters and controllable loads add more dynamics to the grid and need to be measured

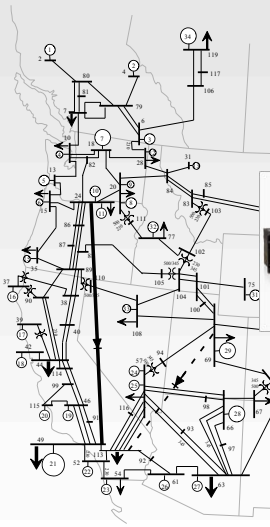
Available SCADA protocols are not designed for high resolution data (4 seconds sampling time)

SCADA data are not time synchronized with GPS

Sensor placement and observability

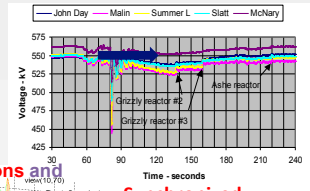


Wide Area Measurement System, Successful in Transmission

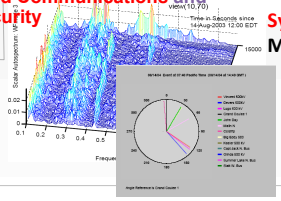


GPS Clock Time-stamped

Enhanced Communications and Data Security



Synchronized Measurements



Useful high quality and real-time information for system operators

Bringing Transmission Level Experience into Distribution

Three Phases
X/R ratios
Unbalances
Asymmetry

Load diversity
Topology Changes
Vulnerability

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"Bad Data"

- If the data doesn't mean what you think it does
- If data is not matched to the standard spec
- If data has:
  - garbage
  - glitches
  - gaps
  - lack of metadata.

Data quality problems are expensive and pervasive

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Data Quality Characteristics

- **Accuracy**: The data was recorded correctly.
- **Completeness**: All relevant data was recorded.
- **Uniqueness:** Entities are recorded once.
- **Timeliness**: The data is kept up to date.
- **Physical Consistency**: The data agrees with system.
- **Synchronization**: measurements are recorded with consistent time stamps at different locations.

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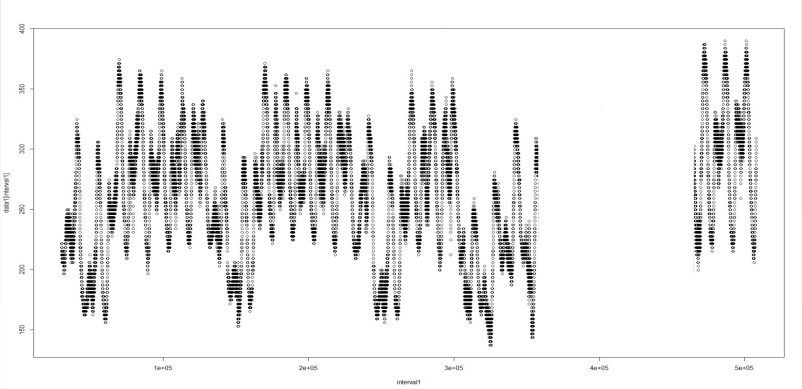
Examples of Bad Data detection

1. Missing Data-Before Cleaning



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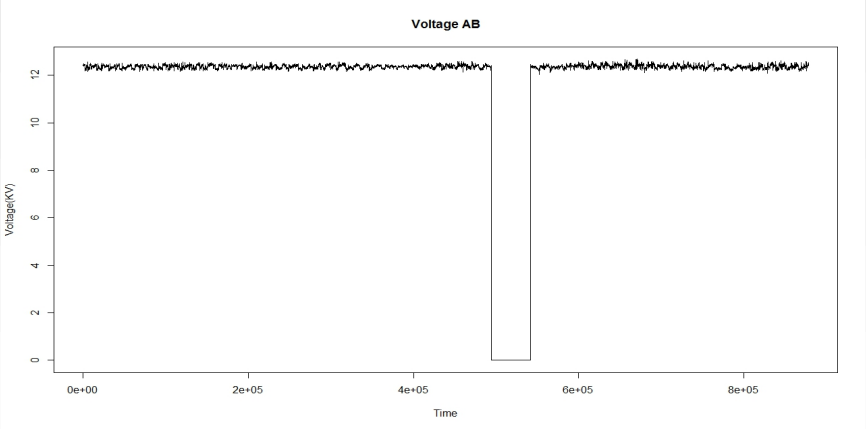
Examples of Bad Data detection

2. Zero Values-Before Cleaning



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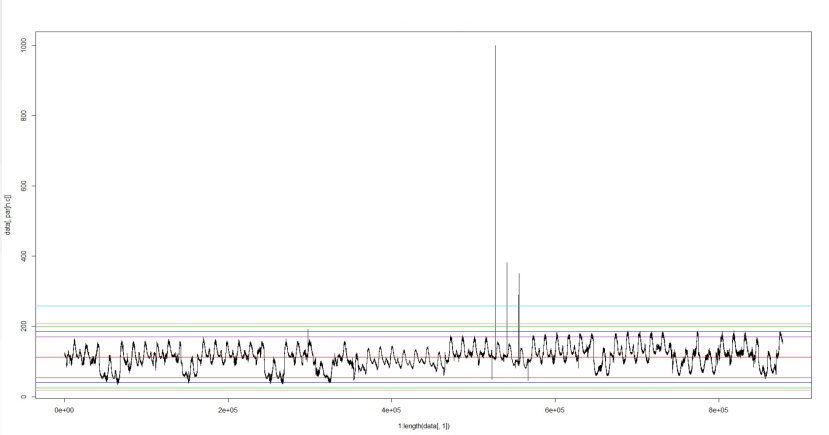
Examples of Bad Data detection

3. Outliers-Before Cleaning



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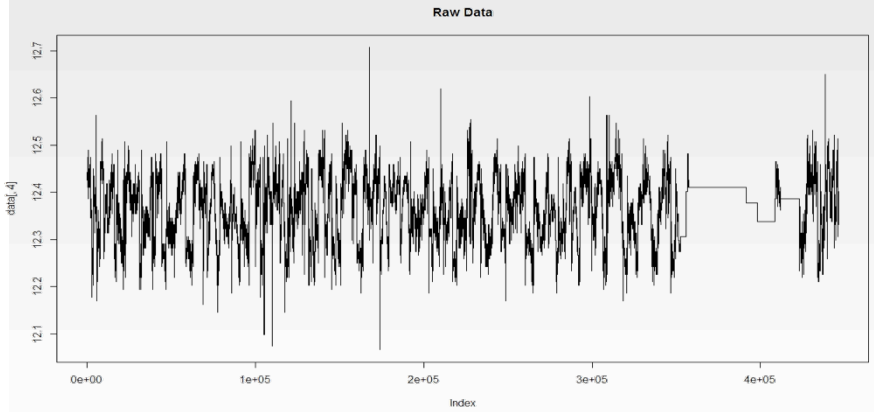
Examples of Bad Data detection

4. Incorrect values before cleaning



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Filling the Gap with Advanced Monitoring

- Making capable database for measurement big data storage
- Adding more intelligence to the data mining for bad data detection, data classification, and pattern recognition
- Taking advantage of measurement data including AMI in operation and planning
- Using high resolution measurement data to monitor system fast behaviors
- Extend system observability with different type of sensors (line sensors, fault detectors, harmonic measurement, synchrophasors…)

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Utility Survey of Current and Future Distribution System Monitoring Needs

presented at:

Distribution Monitoring for Renewables Integration (DMRI) Project Workshop

Berkeley, CA

September 5, 2014

by:

Lloyd Cibulka

Electric Grid Research Team

ciee | California Institute for Energy and Environment

Purpose of Survey ("Questionnaire")

- Provide a foundation of understanding of the current practices and perspectives of the utility industry in California, regarding distribution system monitoring.
- Obtain information from utilities regarding:
  - present-day practices in distribution monitoring
  - what are the critical issues and challenges to monitoring today
  - what technologies, methodologies, applications, etc. are needed (or desired) to meet the monitoring needs of the future distribution grid
- Use information in developing a "strawman" Advanced Monitoring Plan as a basis for research activities that will advance the state of the art of distribution monitoring in the California electric system.

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Question #1(a): Applications (Now)

"What are the most important applications or functions on your distribution system at the present time?"

- Volt/VAR monitoring & control (4)
- A-FLISR (3)
- anti-islanding (inverter-based) (2)
- public safety
- renewables integration
- coordinated fault/overcurrent protection
- switch status
- fault detection/location (2)
- AMI
- settings and coordination on DA equipment
- reactive support for transmission
- CVR
- outage management (via AMI)
- central power plant & critical loads status
- load current
- frequency
- remote monitoring and control of devices
- substation transformer monitoring

Variety of applications, but fault location and V/V control important

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Question #1(b): Applications (Future)

"What are the important applications/functions that your company is planning to implement in the future?"

- understand impacts of, and maintain reliability with, inverter-based DG (4)
- VVO (3)
- anti-islanding (system-based)
- state estimation
- interface with customers to manage energy usage
- expanded use of A-FLISR
- more apps using AMI/Smart Meter data, e.g., load monitoring and control
- apps using distribution PMU data
- energy storage
- fault location
- demand response via EVs
- load ramp detection and planned response
- DG real-time and forecasted output (15 min - 1 hr)
- phase load balance monitoring and control

Top apps: Monitoring DG and Volt/VAR Optimization

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Question #2: Monitoring Status

"What are the basic types of data monitoring currently performed on distribution? Do you have any plans for improving your data monitoring capabilities for current or future uses?"

Now:

- "SCADA (7): V, I, P, Q, alarms, trends, status at substations and line devices
- voltage and harmonics at capacitor controllers
- AMI & Smart Meters
- PQ
- Metering at all loads
- V, I, P at critical switches
- PMUs at select locations
- monitoring for above applications

Future:

- AMI/Smart Meter data (3)
- install more μPMUs (3)
- high resolution monitoring on large (>1MW) DG
- more locations on the system
- V and I in remote operated switches and automated reclosers
- additional monitoring points for state estimator
- fault current data
- topology detection
- reverse power flow

Now: SCADA Dominates ***Future: Add Smart Meter & Hi-Rez Data***

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Question #4: Issues & Challenges

"What is your greatest area of concern for your current distribution monitoring system?"

- visibility (limited to SCADA, or no SCADA in some locations)
- DG "masking" load
- uncertain loading during reconfiguration
- lack of monitoring on the 12 kV primary distribution system
- fault detection/location (3)
- ongoing maintenance/troubleshooting
- voltage support due to DG penetration
- bandwidth
- capability to integrate new sensors with legacy systems
- determination of the proper type and level of data gathering for current and advanced operations
- "health of communication systems"
- lack of adoption of a CIM model
- need for system modeling to guide monitoring plans
- determining optimal locations of sensors
- precision of sensor measurements

Top Concerns: "Visibility" (red) and Fault Detection/Location

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Question #5: Observability

"Which parts of the distribution network need (or will need) more observability (and why)? Substation lines or loads? Generators, components? Microgrids?"

- DERs: DGs, EVs, batteries, solar PV systems, microgrids (6)
- circuits with high levels of DG (3)
- distribution circuits [feeders & secondaries] (4)
- substations without SCADA
- SCADA in urban networks, and in substations near large PV installations
- storage devices
- DSVCs
- switches
- end-of-line measurements for voltage violations
- asset health sensors for condition-based maintenance

Most Important: Need to Know What DG Is Doing!

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Question #6: Data Requirements

"What granularity of measurement do you think is needed, in time and space? E.g., 1-second data? 1-minute data? How many monitoring points per distribution feeder? E.g., at every line device?"

- "it depends"; need to determine specs for individual applications (3)
- 5 second data ("adequate for our applications")
- 1 second within deadband (i.e., typical SCADA); alternative is min, max and average over a 1 minute period; mid-point of circuit at a minimum, and each capacitor, auto recloser and battery storage device
- 6 second polls and 1 minute averages should be sufficient; at a minimum you'd want the substation, the point of interconnection, any NO switch, and any line device
- 60 Hz data; every 1,000 ft (ideally)
- 1 minute load data; 1-3 seconds for device operations
- 2 second data in substations; 5 minute data on line sensors; AMI status data for outage management; ideally on each capacitor, voltage regulator and large transformer

No Clear Consensus – Reflects Uncertainty re: Future Application Requirements

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Question #8: Benefits

"What benefits would you want to achieve from wider deployment of measurement systems?"

- better operational visibility of loads and generation
- ability to transfer distribution circuits effectively
- detect high-Z faults, fault location
- greater operator visibility and control
- full observability of the network to enable system-wide state estimation
- facilitate renewable integration
- understanding of characteristic profiles of connected devices
- correct programming of voltage support devices
- CVR
- system optimization
- algorithms to present the operator with suggested and ranked control actions
- better understanding of the impacts of PV intermittency on the distribution system and subsequently on customer loads
- increased safety, reliability, efficiency and operating flexibility (2)
- better system protection

Recurring Theme: Increased Visibility & Situational Awareness

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Question #10: Synchrophasor Data

"What is or might be the importance of having real-time phase angle measurements and, in general, time-synchronized measurements in distribution networks?"

- incipient & post-disturbance analysis (3)
- detecting and responding to FIDVR events
- analyze transient conditions, protection systems, how events evolve
- avoidance of cascading failures
- voltage instability detection and control
- condition/health of the system (2)
- "not necessary now" – see what future brings
- model tuning and validation
- more precise real-time control
- protection schemes with lines connected to DGs or microgrids
- microgrid re-synchronization/restoration
- fault location
- monitor DG performance in real time
- "we're looking to the ARPA-E project for answers to this question"

Interesting Theme: "Early Warning" Systems for Transient & Dynamic Events (red)

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Question #11: Control

"How do you envision the DMS and/or distribution control systems evolving to meet the challenges of a more complex distribution system? What are the challenges regarding control architecture (distributed versus hierarchical)?"

Evolution:

- situational awareness of various devices connected to the distribution system
- interface to PQView for data historian functionality
- high-speed data collection and state estimation using geo-synchronized data
- eventually include real-time automated feedback control, incl. VVO
- centralized control for efficiency; local control in emergencies
- DMS will become vitally important as distribution systems evolve
- more decentralized control
- "data-enriched" operation systems

Challenges:

- determining proper balance between distributed and centralized control (4)
- operator confidence in autonomous monitoring & control of field devices
- advanced DMS equipment is needed to handle the amount of data, data base integration and required analytics
- adequate personnel training
- field demonstrations before full acceptance

Common Theme: Where's the Boundary between T and D Control Regimes?

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Question #12: Data

"How do you envision the data processing/archival/computational architecture to be implemented?"

- OSI Pi for SCADA data archival, and MDSS (Itron) for AMI data
- PQView™ for post-event analysis with a more interactive GUI to aid system operators
- some data will likely be processed based on exception reporting to limit the computational load, while not compromising observability
- will be utility-specific
- local processing & caches of data at the edge of the grid, communication backhaul of processed data (smaller datasets) to centralized control
- high performance computing, parallel processing, GPU computing architectures in hierarchical distribution network management structure

Divergent Views on This Topic – Also Highly Application-Dependent

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Question #14: Communications

"What are the challenges regarding communication systems and data protocols to support enhanced distribution monitoring systems? E.g., time to implement, cost, labor or other resources?"

- limited bandwidth (4)
- latency (2)
- IT security (2)
- "The benefits that these complex systems have already produced appear limited by the lack of funding and sufficiently trained staff."
- "entrenched" protocols & legacy systems
- cost
- "no major concern in this area"
- in a nutshell: cost, reliability and complexity
- "all the above"

Top Challenges for Future Systems Not Too Different from Current Systems

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Question #15: Challenges

"In terms of monitoring system implementation, what parts are more challenging? Sensor capabilities, communication, or databases? Labor or budget?"

- limited budget & difficulty of justifying cost to management (5)
- high-voltage, low-cost, wide-bandwidth, easy-to-install sensors (3)
- communications & associated "backroom" IT systems, e.g., databases (3)
- labor (2)
- keeping the system going after the implementation phase is over
- new standards & associated workforce training; lack of communication infrastructure (more satellite and 4G needed)
- two-way communications for status and control
- application algorithm development
- data analysis & computational requirements ("Big Data")
- "all the above"

Recurrent Themes: Budget and Human Resources

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Question #13: "Ideal Monitoring System"

"If you were to design the ideal distribution data monitoring system, what would it look like?"

- "There are no ideal monitoring systems. All approaches involve trade-offs."
- inexpensive devices; automated end-point test with plug & play functionality; radio communications capabilities; higher resolution for events analysis; line post sensors pre-wired on crossarms; IEEE 1159.3 PQDIF data format capability
- There needs to be two data monitoring systems:
  - Operator's system would look very familiar to what is currently in place with a little bit of extra monitoring to accommodate for distributed generation.
  - Engineer's system would utilize the operator's system, but with a higher resolution data set with accurate time stamp. Would require additional hardware, e.g. PQ meters; a minimum of 15 min AMI usage and voltage data; accurate GIS circuit representations.
- Broadband, high speed, cyber secure, high level of reliability (some redundancy), minimal installation cost, easy to add additional end points with minimal costs, long range, data filtering capability, unlimited storage capacity, compatible with any visualization analytical software

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"Ideal Monitoring System" (cont'd.)

- much more DC technology to enable the fast and efficient controls necessary for a modern grid, e.g., develop and apply distribution matrix transformers (basically back to back converters) for better control and protection
- CIM model-based, low latency, variable resolution, smart compression, low frequency/duration of communication outages, better UI design for human operators
- an optimal composition of various data monitoring technologies that are available today and in R&D phase (SCADA, sensors, AMI, etc.)
- Analytic Software + Mapping System + Power Quality Meas >> Decision Making Algorithm >> DMS

Many Divergent Opinions about "Ideal" Attributes of a Monitoring System

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Takeaways from Survey

- budget and manpower are seen as big challenges
- visibility & situational awareness for operators is key: need status of DGs, key loads and system devices
- applications to aid operators will be needed
- lots of uncertainty around data resolution & accuracy specs (applications-driven)
- communications will be a big challenge
- a variety of visions about future distribution system control structure
- **no common vision of an "ideal" distribution monitoring system…**
- …although there are lots of interesting aspects that people foresee or want

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'Straw Man' Advanced Monitoring Plan: A Wish List for Filling Gaps and Answering the Questions at Hand

presented at:
Distribution Monitoring for Renewables Integration (DMRI) Project Workshop
Berkeley, CA
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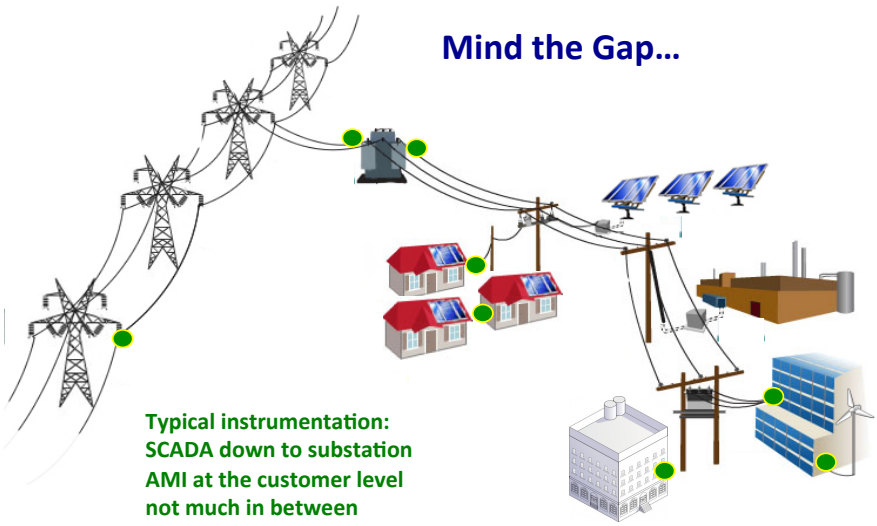
ciee | California Institute for Energy and Environment

by:
Bob Russ
Consultant

Mind the Gap…



Typical instrumentation:
SCADA down to substation
AMI at the customer level
not much in between

General Considerations for AMP

- Every utility has a unique ecosystem (i.e. needs, organizational sensitivities, available $s/resources/people, technology maturity, legacy issues, etc.)
- Which includes: customer premise equipment (HAN, ESS, EVs, DG, etc.), Internet of Things ('edge' devices), migration from centralized to more local control, ever decreasing electronic costs (especially in processing/storage)
- AMP does not have to be a 'cost-center', it can be part of a bottoms-up technology approach and financial analysis that pays for itself
- AMP Approach is very different if told $X/yr vs justify $s (loss, risk, liability, savings, etc.)

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Some 'Big Picture' Questions

- Provide technical guidance on Rule 21, IEEE 1547 changes, grid-support and ancillary services, 'smart' inverters, FERC/NERC, etc.?
- What are appropriate AMP objectives, decision points, and milestones ?
- What are appropriate timeframes ?

- **How organizationally integrated should AMP be?**
- **Is AMP part of a fully integrated utility-wide across all departments architecture, shared access, evolved corporate culture ?**

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Immediate Technical Objectives for Monitoring: Potential Issues to be Identified or Anticipated

- Capacity limitations (secondary transformer overload)
- Reverse power flows and detailed power flows on all phases
- Protection coordination problems (relay desensitization)
- Undesirable voltage profiles (range violation, inverted profile)
- Rapid voltage variations (excessive tap changes, premature wear)
- Harmonics (excessive losses, impact on sensitive loads)
- Phase imbalance (excessive losses, nuisance trips)
- Unintentional islanding possibility
- Collective behavior of inverters (cascading disconnect)
- Impact of advanced inverter functions (LVRT, LFRT, Volt-VAR support)
- Visibility to transmission level/ISO (vulnerability to fast ramps)
- "Sharks" (oscillations, unknowns)

- **Others ?**

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Further Technical Objectives for AMP

- Recall earlier Timescale Diagram Tradeoffs
- Improve Monitoring/Measurement, Control, and Communications
- Establish Baseline for DFs for later comparison (with installed DG/ DER)
- Time-stamped/synced high-resolution data throughout DF
- Identify masked loads
- Determine min/max DER hosting capacity
- Data useable to verify/validate individual DF models including both utility and customer equipment inclusion
- Inform future monitoring and infrastructure investments

- **Can AMP estimate masked loads & other impacts ?**

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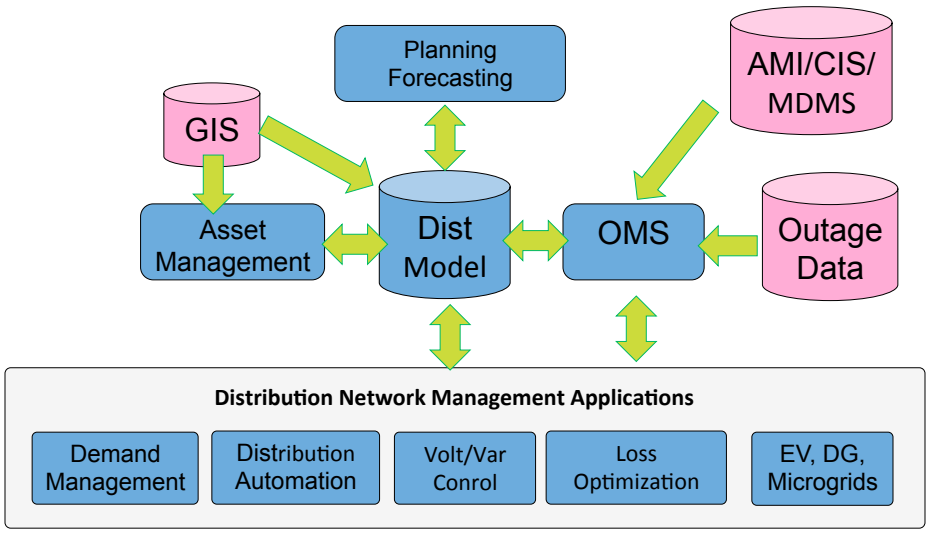
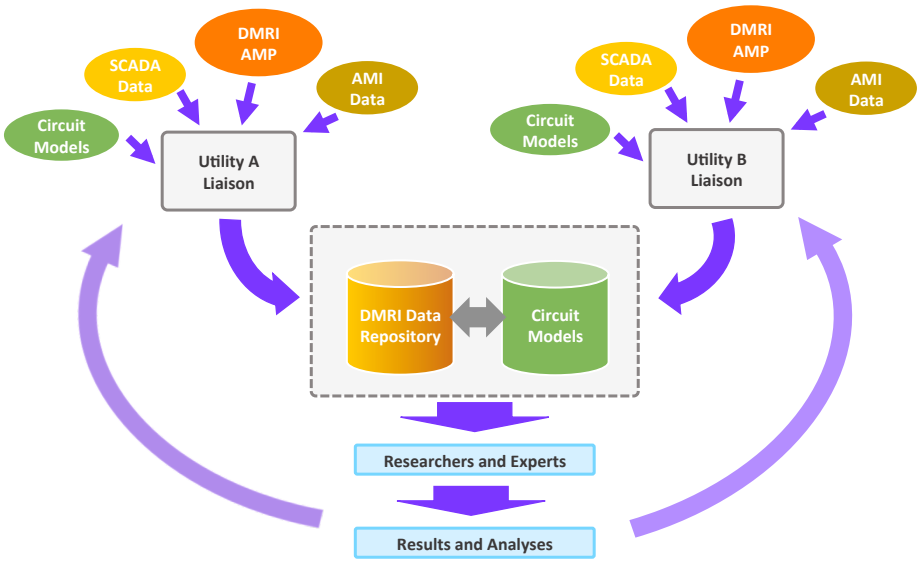
Possible high-level configuration of AMP (1)

Key question: does AMP happen inside or outside existing utility data collection and analysis infrastructure?



Possible high-level configuration of AMP (2)



Key question: does AMP happen inside or outside existing utility data collection and analysis infrastructure?

Working Assumptions

- Monitoring is needed to characterize grid behavior for high DER
  - Need to characterize legacy as a 'control' or 'baseline'
  - Need to monitor for both the 'usual' as well as 'unknown'
- Monitor V and A; also other measurements (for PV, HAN, DR, EV…)
- Measure at sub-station and end-of-line as minimum
- Need to generalize utility distribution typology and requirements capture
  - Locational granularity will be judgment call based on cost, complexity, etc.
- Measurement frequency (legacy vs capture for unknowns @1/sec)
- Utility Funding: pay for equipment, install, and communication
- Public Funding: pay for data collection, storage, modeling, and analysis
- DMRI monitoring will be temporary (e.g. a near-term timeframe of 3 years)
- Assume that for the near future that AMI generated data (e.g. 5 sec) will not be readily available for use to augment AMP
- Assume that the default for DF configuration is a more Clustered distribution for PV installs
- Assume that outside data feeds are installed (e.g. local weather, solar insolation, others)
- Assume that AMP has been designed with collaboration in mind (e.g. data formats, location, anonymity, etc.)

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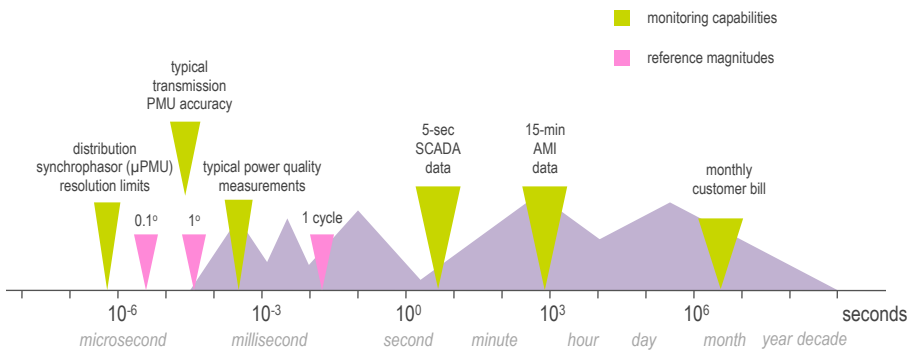
Monitoring Capabilities on a Time Scale



AMP Wishlist (bells & whistles)

- **Capture Existing Information for each Distribution Feeder (DF):**
  - GIS and all locational data, any SCADA data/history, associated weather data, event history
  - Detailed descriptions: OH/UG circuit-miles, 1/2/3 phases, regulators, reclosers, caps, transformer taps, circuit nodes/ geometrics, R/C/I/Ag transformers/eqpt, climate zone, etc.
  - Capture any operating behaviors: capacity factor, min/peak loads, seasonal variations, major event variations, quality of existing information
  - Capture existing customer generation: PV, wind, ESS, fuel-cells, other DER, size, type of inverter(s), controls, behaviors and statistics, etc.

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AMP Wishlist (cont'd)

- **Determine best classification/taxonomy of each DF circuit (or priority ones)**
  - Utilizing either existing DF circuit data (if avail) or AMP data, characterize each
  - E.G. using PNNL's 24 non-urban archetypes and 35 significant descriptors
  - For urban/auto-loop/spot/network DFs, characterize using EPRI's/other method
  - Refine existing taxonomy models to better suit each DF circuit characteristics
  - What has not been captured for DF taxonomies for CA feeders ?

What has not been captured for DF taxonomies for CA feeders?

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AMP Wishlist (cont'd)

- **Ideal Location(s) for placement of Distribution Sensors:**
  - Sub-station DF origin and All significant end-of-line DF branches
  - Every mile and/or every 20% of circuit-length and/or every major vertex
  - Every generation source >100 kVA and every peak load sink >250 kVA
  - Geocentricity of Data and locational spacing (every transformer ?)
  - Account for Clustering and Distributive effects

Don't Forget other Location Requirements (e.g. convenience of installs for accessibility, exposure to elements, and transformer proximity)

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AMP Wishlist (cont'd)

- **Extent of AMP rollout:**
  - Only one DF ?
  - If Coverage objective includes only a few 'known' problem DFs or typical DFs
    - (e.g. 24/2 = 10-15 feeders) ?
  - If Coverage objective includes at least one example for each DF taxonomy
    - (e.g. 24 x 2 = 50 feeders) ?
  - If Coverage objective includes statistical numbers of each major DF taxonomy
    - (e.g. 24 x 2 x 5 = 250 feeders)?
  - Or Plan to rollout to most/all of utility's DFs

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AMP Wishlist (cont'd)

- **Proposed Data Requirements:**
  - For General Sampling: minimum 1 sample/sec and sync/cycle each phase
  - For PQ/high-resolution Sampling: minimum 256 samples/cycle per phase
  - Detailed data (V, A, VA, VAR, harmonics, flicker, sags/swells, etc.)
  - Time-stamped and synced with all other Sensors:
    - General Sampling @0.1 sec
    - PQ/high-resolution @1 usec
  - Accuracy of Data Requirements
  - Additional Data Needs (e.g. weather, solar, wind, CAISO, etc.) ?

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AMP Wishlist (cont'd)

- **General Purpose Sampling:**
  - Sampling @1/sec (e.g. 100MB/month/Sensor)
- **PQ/High-Resolution Sampling:**
  - Sampling (min @256 samples/sec) +/- 10sec around any defined 'event'
  - Sample for 1 cycle every 1 sec (e.g. 5GB/month/Sensor)
  - Sample for 10 cycles every 100 secs
  - Sample for 100 cycles every 1,000 secs
  - Sample for 1,000 cycles every 10,000 secs
  - Other Sampling requirements ?
  - How would these be different if Objectives did not require high-resolution ?

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AMP Wishlist (cont'd)

- **Communications and Storage:**
  - Each Distribution Sensor average-data rate:
    - For PQ/high-resolution sampling <5 kB/sec and DF data rate < 200 kB/sec
    - For general purpose sampling <500baud and DF data rate < 2kB/sec
  - Will likely need data buffering and battery storage for data integrity
  - Precise description of all data fields, lengths, delimiters, etc.
  - Each DF requires storage of approximately 100 GB/month (will be part of utility's 'Big Data')
  - Ideally would use agnostic/open standards for communications (e.g. cellular, IEEE 61850, ...)
  - Choice between utility using their existing communication(s) capabilities or some standardized approach and commonality across all utilities
  - Data protection, channel access, and cybersecurity
  - Privacy and access to data by others (within company; from other companies)

Can AMP data and communications be standardized for ease of collaboration?

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AMP Wishlist (cont'd)

- **Data Processing**
  - Front-end and clean-up requirements
  - Accessible as relational database …some real-world DB Issues?
  - Can be pre-processed as formatted input into statistical packages, modeling data input, algorithm development, financial spreadsheet analyses, etc.
  - Ideally will have visualization interfaces to more easily grasp issues and trends
  - Different Levels of Detail available depending upon internal/ external use ?

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AMP Wishlist (cont'd)

- Model Validation:
  - From AMP Data analysis, determine appropriate range of initial and boundary conditions
  - Perform statistically significant number of simulations on full range of DF circuit operations (e.g. min/peak load, min/peak generation, etc.) and use these to compare to actual monitored measurements and behavior
  - Refine and iterate DF Model to more accurately reproduce measured behaviors

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AMP Wishlist (cont'd)

- Modeling and Algorithm Development Objectives:
  - Ideally use open-source models (e.g. OpenDSS, Gridlab-D, etc.)
  - Perform steady-state, dynamic, and transient analyses of each DF
  - Perform statistically significant number of simulations on each identified 'Future Scenario' that is appropriate to that specific DF

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AMP Wishlist (cont'd)

- Create Range of 'Future Scenarios' for Model Simulations
  - Estimate over appropriate timeframe(s) envelope range extremes:
    - Min/max PV penetration % and best/worst variability
    - Min/max EV penetration % and timing variability
    - Other Potential Customer-driven impacts (e.g. ESS, volt-var support, ESS, wind, etc.)
    - Impact of changes in IEEE 1547/Rule 21 for anti-islanding, 'smart' inverters, etc.
    - Growth of min/max Loads (VA and VAR)
    - Range of likely DF Operations scenarios (e.g. CVR, Volt-Var support,

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Facilitated Discussion of the Straw Man Plan

Merwin Brown
Electric Grid Research Team

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Beyond the DMRI Project

A Facilitated Discussion

Merwin Brown
Electric Grid Research Team

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