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CIGRE Grid of the Future
*Industry Roadmap for Implementation of
Distribution Synchronized Measurements*



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Overview

- Utilities are facing a variety of new distribution system challenges due to a changing environment and added complexity
 - Increasing penetration of Distributed Energy Resources (DERs)
 - Transportation electrification
 - Increasing frequency of major weather events
 - Evolving customer expectations of service reliability
 - Resilience
 - Power Quality
- Synchronized measurements are a necessary and powerful tool to address grid issues and support reliable grid operation during decarbonization efforts

Severe Weather Impacts

- Challenges are diverse and vary by geographic region
 - Severity and duration of droughts, frequency of strong winds, increasing precipitation, average temperature increase, and temperature swings are some of the variables driving these challenges
- In Fig. 1, we look at monthly burned area for the Western United States, where utilities have faced unprecedented wildfire risk levels
- Distribution grids, given their expanse and largely overhead design, are particularly vulnerable to severe weather events and exposure to other external factors such as aggressive vegetation

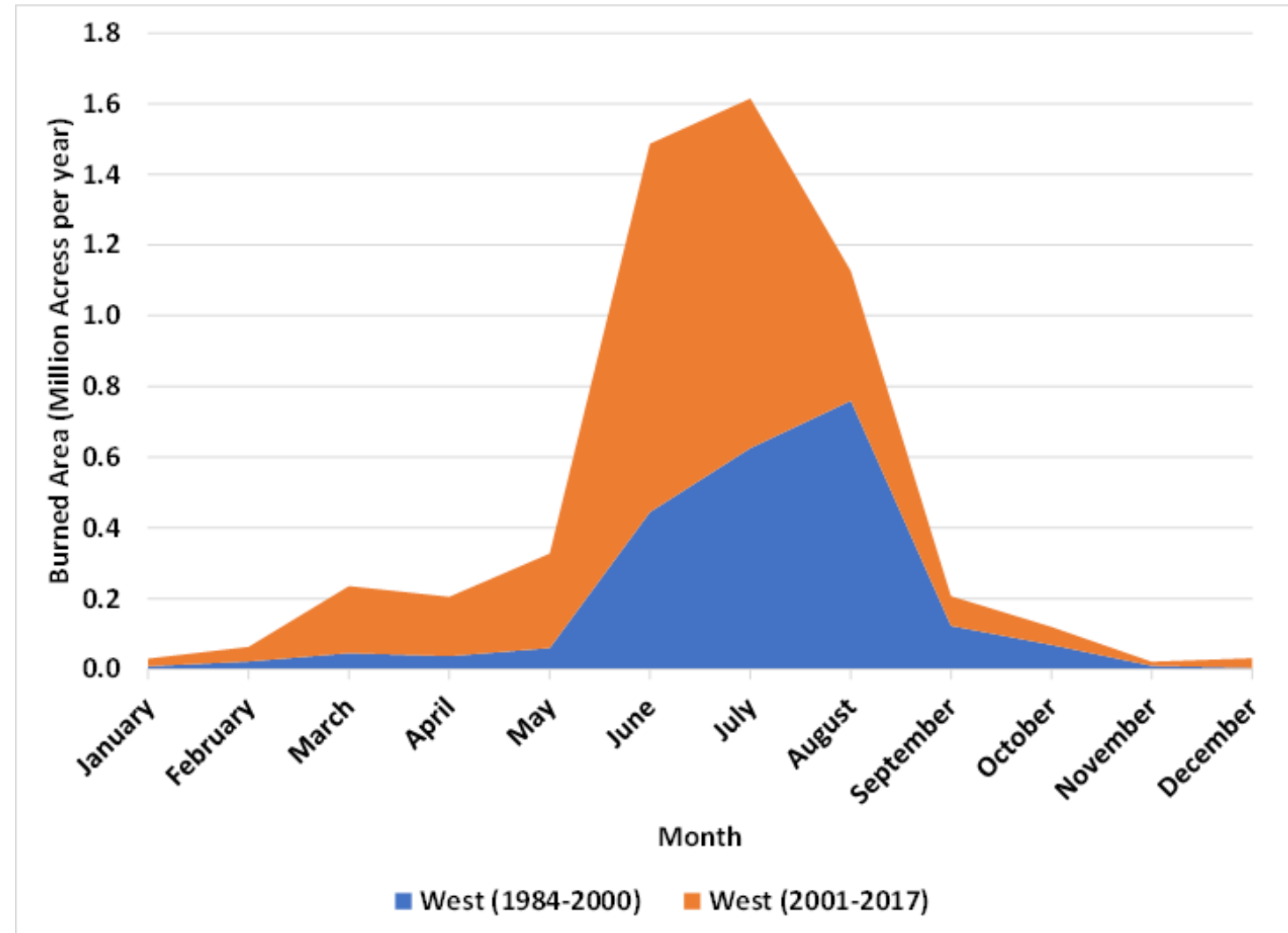


Figure 1. Monthly burned area due to wildfires in the Western United States between 1984–2000 and 2001–2017 [1]

Cases of Reverse Power Flow

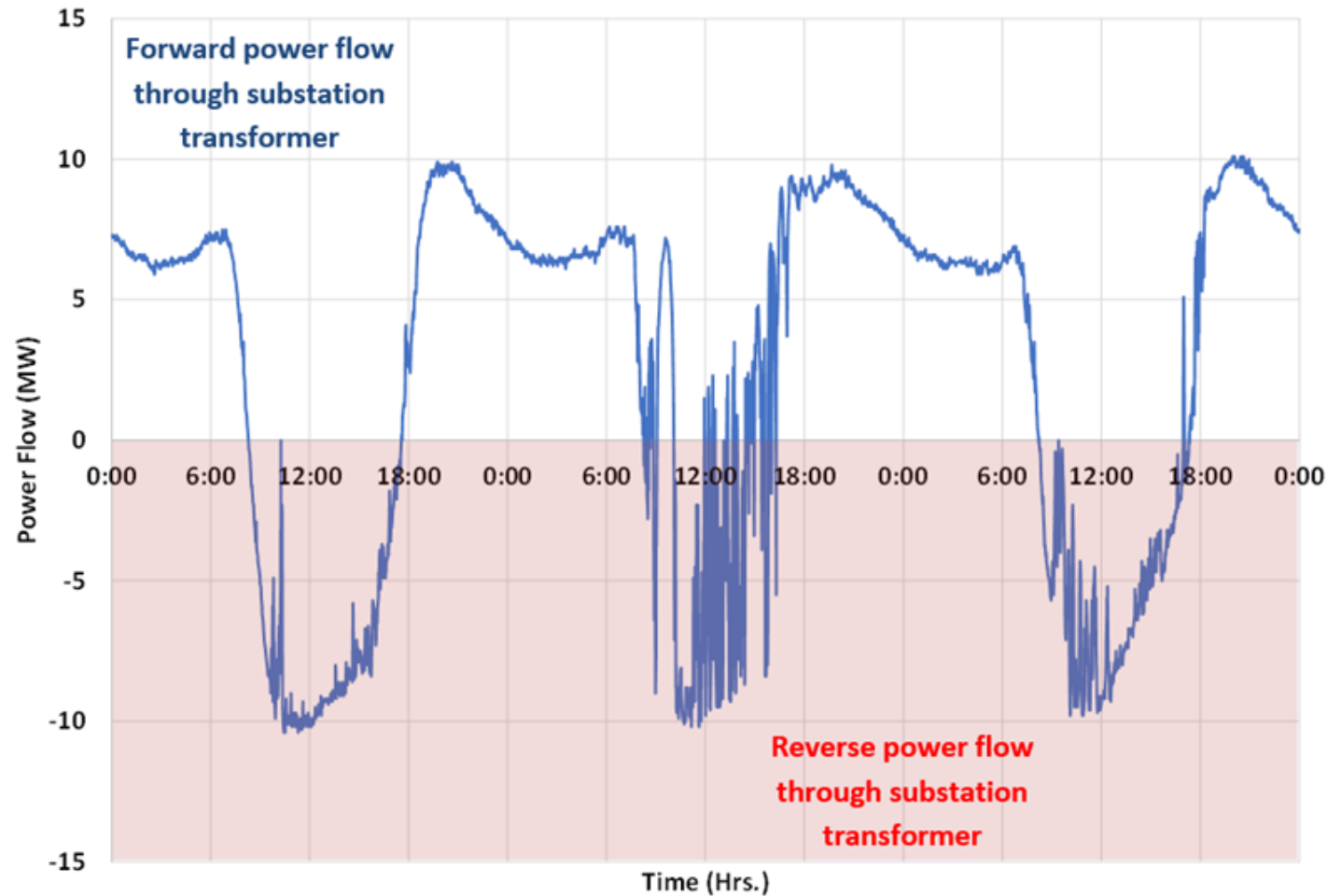


Figure 2. Power flow fluctuations through a real distribution substation in Virginia due to high adoption of photovoltaic (PV) distributed generation [5]

Predicted Increase in Peak Demand – Shift to Electric Vehicles

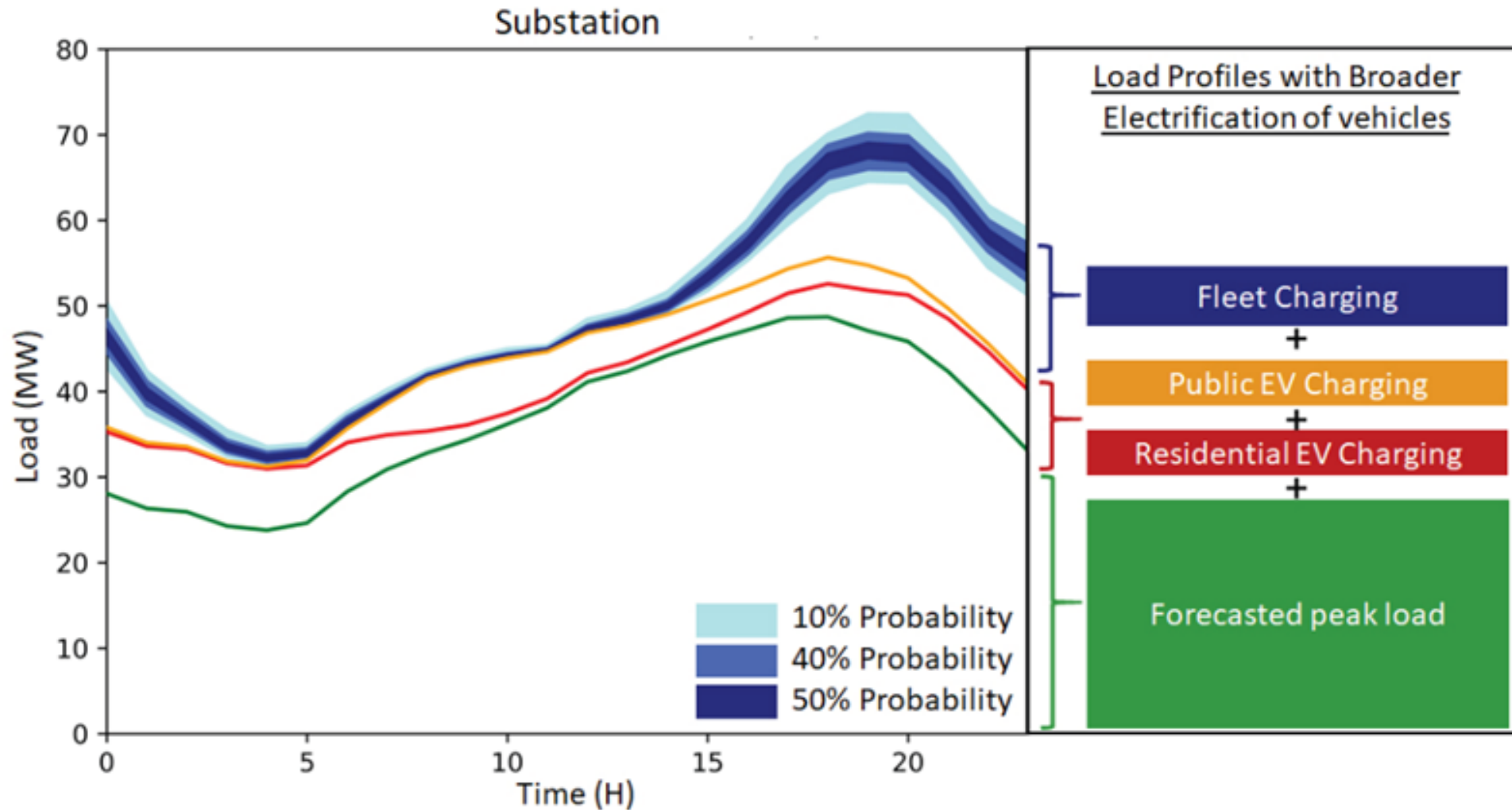


Figure 3. Forecasted impact of EV charging on daily substation load profile if 100% of vehicles are electric [7]

Prevalence of Oscillations in the Distribution System Due to DER Penetration

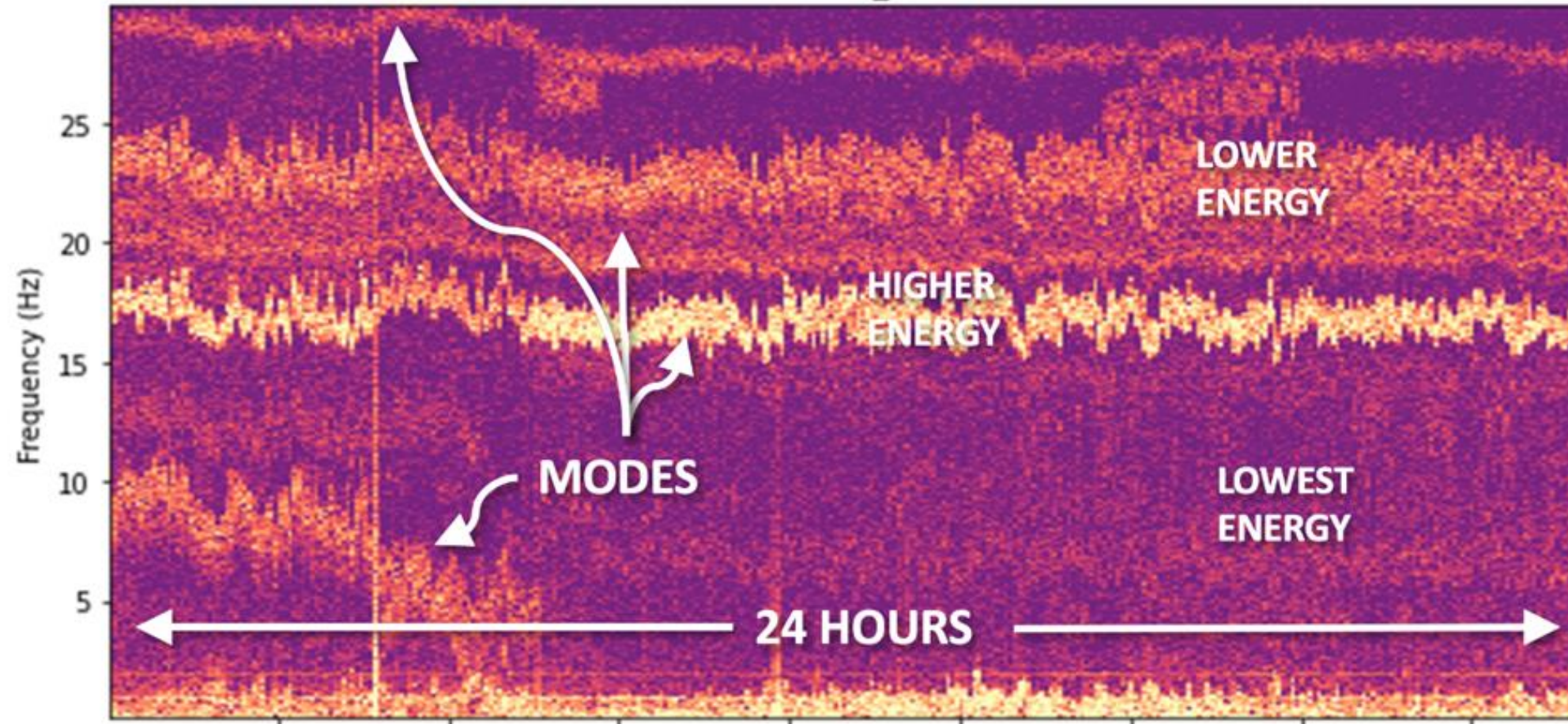


Figure 4. Example spectrogram demonstrating the prevalence of and dynamic nature of persistent modes of oscillation in the Dominion system

Industry Roadmap: Identified Application Groups and Underlying Applications

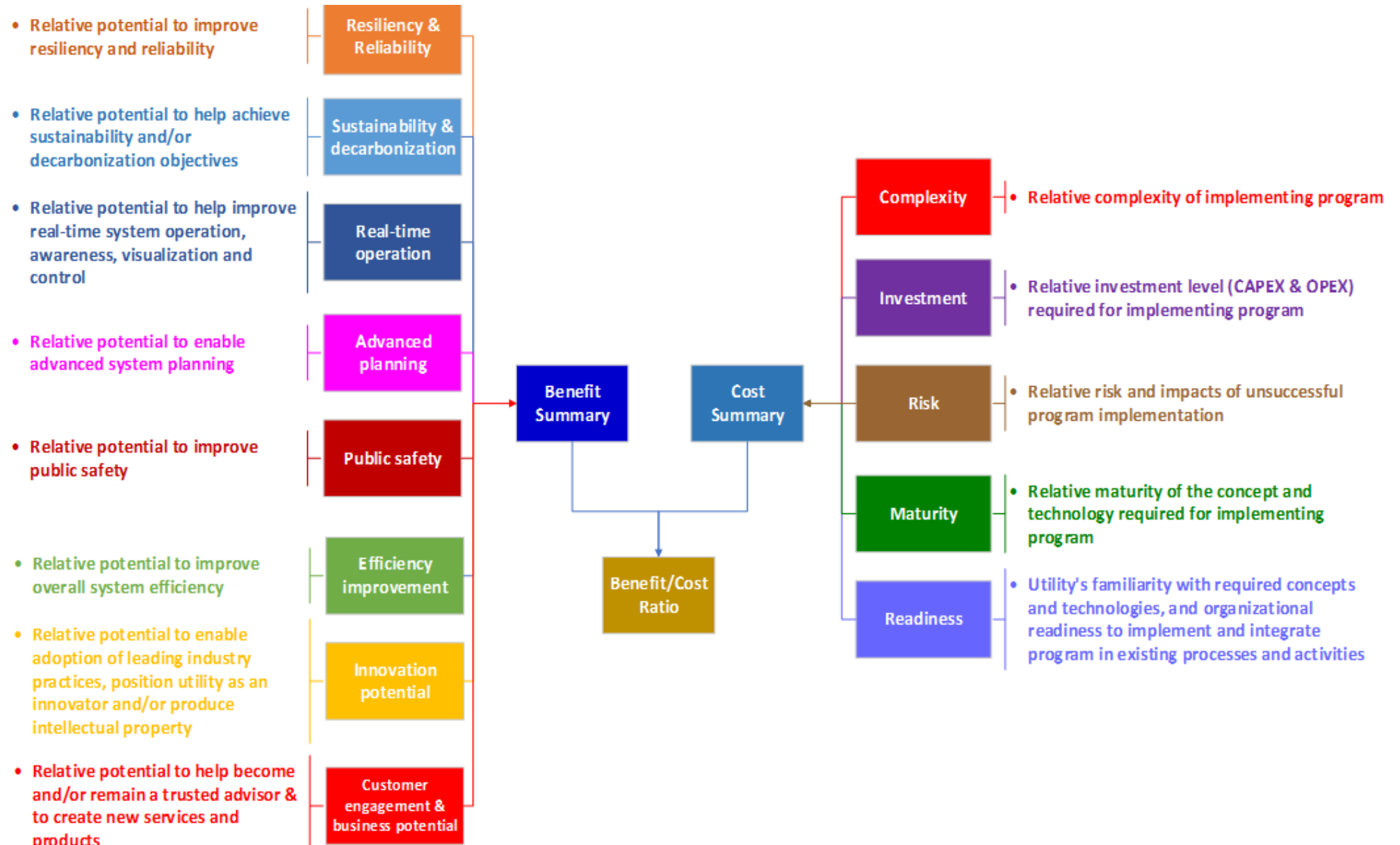
Table 1. Distribution synchronized measurement applications and associated application groups

Application	New Use Case Description	Application Group Number	Proposed Application Group Description
A1	Conservation Voltage Reduction (CVR)	AG1	Advanced Volt-VAR Control (AVVC)
A2	Volt-VAR Control (VVC) of distribution systems		
A3	Volt-VAR Optimization (VVO)		
A4	Active and reactive power flow monitoring	AG2	Advanced monitoring of distribution grid
A5	Voltage profile monitoring		
A6	Communications system/equipment performance with management metrics monitoring		
A7	Frequency monitoring	AG3	Asset management of critical infrastructure
A8	Near real-time event monitoring (physical)		
A9	Near real-time event monitoring (cyber)		
A10	Phase angle monitoring for voltages and currents		
A11	Power apparatus asset management		
A12	Power apparatus functional monitoring		
A13	Monitoring and control of critical infrastructure and large customers	AG4	Wide area visualization
A14	Underground secondary/spot network monitoring and analysis		
A15	Dynamic rating of distribution assets		
A16	Circuit status dashboards	AG5	DER integration
A17	Integration of customer site FNET information		
A18	Improved wide-area situational awareness (T&D)		
A19	Visualization of dynamic system response	AG6	Real-time distribution system operation
A20	Monitoring of intermittent DER		
A21	Voltage impact assessment and mitigation due to high penetration of intermittent energy resources		
A22	Active and reactive reverse power flow management	AG7	Enhanced reliability and resiliency analysis
A23	Customer/smart inverter control		
A24	DER management and energy balancing with energy storage		
A25	Load unmasking (behind-the-meter DER)	AG8	Advanced distribution system planning
A26	Distribution state estimation		
A27	Closed-loop circuit operation		
A28	DERMS implementation	AG9	Distribution load, DER, and EV forecasting
A29	Improved demand response		
A30	Improved distribution reliability analysis		
A31	Post-mortem analysis	AG9	Distribution load, DER, and EV forecasting
A32	Phase identification		
A33	Distribution system computational model validation		
A34	Short-circuit study validation	AG9	Distribution load, DER, and EV forecasting
A35	Load characterization, load modeling, and load forecasting		
A36	DER forecasting		
A37	EV forecasting	AG9	Distribution load, DER, and EV forecasting

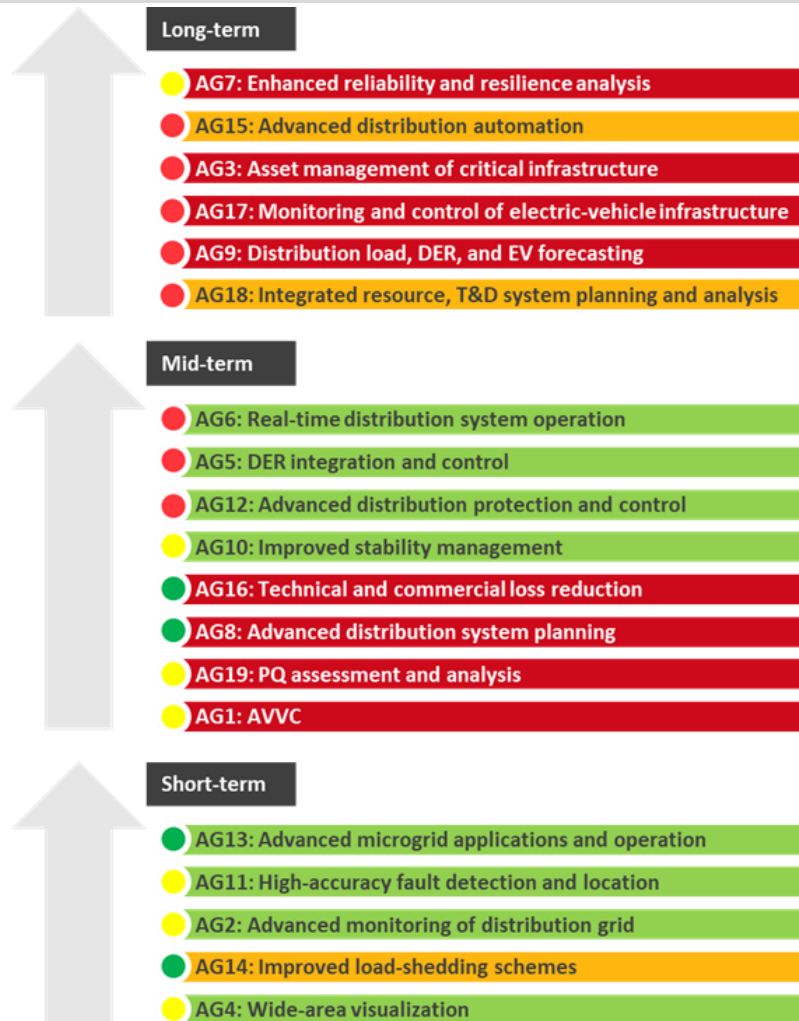
A38	Voltage stability monitoring and control	AG10	Improved stability management
A39	Control instability, hunting, or oscillation detection (voltage, VAR, switching)		
A40	Transient stability monitoring and control		
A41	Fault-Induced Delayed Voltage Recovery (FIDVR) detection	AG11	High-accuracy fault detection and location
A42	Faulted circuit indication		
A43	Incipient fault and failure detection		
A44	High accuracy fault location	AG12	Advanced distribution protection and control
A45	Communications failure location for maintenance dispatch		
A46	High impedance fault location		
A47	Open conductor fault location	AG13	Advanced microgrid application and operation
A48	Falling conductor protection		
A49	Reclosing assistance for fast circuit recovery after fault		
A50	Current differential protection of circuit sections	AG14	Improved load shedding schemes
A51	Adaptive protection of distribution systems		
A52	Planned islanding and restoration of microgrids		
A53	Advanced protection of microgrids	AG15	Advanced distribution automation
A54	Advanced distribution system topology, automation, and control (holonic grids)		
A55	Islanding detection for distributed generation (anti-islanding scheme)		
A56	Improved load shedding schemes (frequency)	AG16	Technical and commercial loss reduction
A57	Improved load shedding schemes (voltage)		
A58	Improved load shedding schemes (load flow-based)		
A59	Load shedding real-time compensative arming to balance 1547-compliant PV	AG17	Monitoring and control of electric transportation infrastructure
A60	Load transfer and load balancing		
A61	Self-healing and enhanced FLISR operation		
A62	Circuit loss minimization	AG18	Integrated resource, transmission, and distribution system planning and analysis
A63	Energy accounting		
A64	Technical and commercial loss identification, calculation, and reduction		
A65	Monitoring and control of electric transportation infrastructure	AG19	Power quality assessment and analysis
A66	Vehicle-to-Grid (V2G) monitoring and control		
A67	Running sub-transmission (69 kV) and distribution in parallel		
A68	Integrated resource, transmission, and distribution system planning and analysis	AG19	Power quality assessment and analysis
A69	Harmonics measurement		
A70	Voltage sag and swell measurement		
A71	Flicker measurement	AG19	Power quality assessment and analysis
A72	Voltage and current imbalance measurement		
A73	Short-duration interruption measurement		
A74	Harmonic state estimation/diagnosis	AG19	Power quality assessment and analysis
A75	Primary meter customer (e.g., major customer monitoring power quality)		



Evaluating Relative Benefit and Cost



Industry Application Roadmap from DOE Investigation



Key:

Difficulty to implement:

- Low
- Medium
- High

Synchronized measurements:

- Necessary for critical applications
- Provide added benefits for critical applications
- Provide added benefits for moderate applications

Group	Description	Benefit Numerical Assignment	Cost Numerical Assignment	BCR
AG1	Advanced volt-var control	4.54	4.65	0.98
AG2	Advanced monitoring of distribution grid	6.64	5.35	1.24
AG3	Asset management of critical infrastructure	5.94	6.65	0.89
AG4	Wide area visualization	7.00	5.70	1.23
AG5	DER integration and control	6.62	6.10	1.09
AG6	Real-time distribution system operation	6.70	6.00	1.12
AG7	Enhanced reliability and resilience analysis	4.58	4.95	0.93
AG8	Advanced distribution system planning	4.42	4.35	1.02
AG9	Distribution load, DER, and EV forecasting	5.26	6.55	0.80
AG10	Improved stability management	5.28	5.00	1.06
AG11	High-accuracy fault detection and location	7.30	5.55	1.32
AG12	Advanced distribution protection and control	6.72	6.30	1.07
AG13	Advanced microgrid applications and operation	6.26	4.60	1.36
AG14	Improved load shedding schemes	5.42	4.40	1.23
AG15	Advanced distribution automation	5.42	6.00	0.90
AG16	Technical and commercial loss reduction	4.16	4.05	1.03
AG17	Monitoring and control of electric transportation infrastructure	5.26	6.05	0.87
AG18	Integrated resource, transmission, and distribution system planning and analysis	5.18	7.40	0.70
AG19	Power quality measurements	4.86	4.80	1.01

Applying to Individual Utilities

- This report is based on industry-wide feedback and the prioritization of needs and use cases for an individual utility may look very different from what is presented in this paper
- This report can be leveraged to help identify key applications and the process that was used to determine the relative benefits and costs of each application
- Each utility should consider:
 - Individual business needs
 - Problems in need of the most urgent solutions
 - Placement of synchronized measurement devices throughout the system
 - Available infrastructure and telecommunications



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Thank You!
Questions?