



California Energy Commission PIER Smart Grid Roadmap Study May 14, 2009



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Project Scope and Contents

- Steps in Project
 - Market Analysis of Smart Grid Technologies
 - Trends Analysis
 - Growth Patterns
 - Market Factors Affecting Market Development
 - Regulatory Issues Affecting Market Development
 - Design (Technical) Factors Affecting Market Development
 - Analysis of Relationship of Renewables Penetration to Smart Grid Technologies
 - Gap Analyses and R&D Recommendations / Prioritization
- What is “Smart Grid” in Project Context?
 - Transmission: Phasors, FACTS devices, new technologies, Substation Automation
 - Distribution: Substation and Distribution Automation; Advanced Planning and Engineering Software; Communications
 - Storage
 - Advanced Metering
 - Home Automation; Building Automation; Distributed Renewables; Distributed Storage
 - Renewables Integration – Planning, Operations, Markets

Facilitating Renewables Penetration

- Reduce Capital Costs
 - Interconnection
 - Capacity Ratios
- Renewables Operating Economics
 - Market Participation
 - Reduced T&D Costs
 - Reduced Output Limits/Curtailments
- Facilitate Interconnection
 - Bidirectional distribution circuits
 - System Reliability Issues
- Power System Capital Costs
 - Transmission Expansion
 - Distribution Capacity
 - Conventional Generation (Back up, ancillaries)
- Wholesale Economics
 - Congestion Costs
 - Losses
 - Capacity Payments
 - Generation Capacity
 - Energy Prices
- Functional Value to Consumer
 - Reduced Energy Prices
 - Less Inconvenient Demand Management
 - Improved Reliability

Smart Grid Tactics for Facilitation

- Visibility of Renewable Production
- Visibility of Renewable Capacity
- Control of Renewable Production
- Dispatchable Renewables
- Balancing / Levelizing Renewable Production
- Green PHEV Charging
- Improved Circuit Ratings
- Improved Volt / Var Coordination
- Enable Hourly Pricing
- Behind the Meter Demand Integration
- Behind the Meter Renewables Integration
- Increased Demand and Renewables Participation in Markets
- T&D Asset Management
- Distribution Reliability Improvements
- Transmission Reliability Improvements

Smart Grid Technologies to Support Tactics

- Intelligent Electronic Devices
 - Phasor Measurements
 - Bidirectional Protection and Control
- Application Support Systems and Software
 - Transmission Operations
 - Distribution Planning
 - Distribution Operations
 - Advanced Asset Management
- Substation and Feeder Automation and Communications
 - Incorporate Variability and Bidirectional Operation
 - Substation Storage
- Electricity Storage
 - Grid Connected
 - Distributed / Community Storage
 - Behind the Meter Storage
 - Storage at Large Central Renewable Sites
- Building Automation
 - Autonomous Demand Response
 - Integrated Renewables and Storage Control
- Home Automation
 - Behind the Meter Renewables Integration
 - PHEV Charging
 - Low Voltage Wiring
 - Smart Appliances
- PHEV Integration
 - Managed Charging
 - Meter on the Vehicle
- Grid Stabilization
 - Synthetic Inertia
 - Synthetic Governor Response

Renewables Facilitation Objectives – Smart Grid Tactics

Smart Grid Renewables Facilitation Matrix	Renewables Facilitation Objectives ↓	Smart Grid Tactical Objectives • →	Facilitation Objective Rank >	Visibility of Renewable Production	Visibility of Renewable Capacity	Dispatchable Renewables	Control of Renewable Production	Balancing / Leveling Renewable Production	Green Charging PHEV Integration	Improved Circuit Ratings	Improved Volt/ Var Control	Enable hourly pricing	Behind the Meter Demand Integration	Behind the Meter Renewables Integration	T&D Asset Management	Distribution Reliability	Transmission Reliability	
	Reduce Renewables Capital Costs	Interconnection Costs	Ref												27			32
		Capacity Ratios	Ref	1	7			16	24			20						
	Improve Renewables Operating Economics	Market Participation	Ref	2		20	10						21	26	27			
		Reduced T&D Losses	Ref	3		20					18	19				28		
		Reduce Limitations on Output	Ref			20		16			18							
	Facilitate Interconnection	System Reliability	Ref	4	7		11									28		30
		Bidirectional Flow	Ref	5		21	12											
	System Capital Costs	Transmission expansion	Ref	6	8	22	13	17			18		22			28		30
		Distribution Capacity	Ref	6	7		13					19			27			
		Conventional Generation	Ref			22												
	Indirect Wholesale Power System Economics	Congestion costs	Ref			23	14	19			18							
		Losses	Ref				14											
		Capacity Payments	Ref			23												
		Generation Capacity	Ref		9													
		Energy Prices	Ref			23			24					26				
	Functional Value to Consumer	Reduced Energy Costs	Ref							25			23	26			29	
		Less Inconvenient Demand Management	Ref							25			24	26	27		29	
		Improved Reliability	Ref														29	

Cells link to description/exposition
and to Rankings

Smart Grid Tactics - Smart Grid Technologies

Smart Grid Renewables Categories	Smart Grid Technologies	Smart Grid Technical Objectives ↓	Ref	Visibility of Renewable Production	Visibility of Renewable Capacity	Dispatchable Renewables	Control of Renewable Production	Balancing / Lowering Renewable Production	Green Charging PHEV Integration	Improved Circuit Ratings	Improved Volt/Var Control	Enable hourly pricing	Behind the Meter Demand Integration	Behind the Meter Renewables Integration	Increased Demand and Distributed Participation in Markets and Operations	T&D Asset Management	Distribution Reliability	Transmission Reliability	
				Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =	Score =
Categorized as Integration	IEDs	Wide Area PMU	Ref																
		BiDirectional Protection	Ref																
CEC Transmission & Distribution Category Area	Application Support Systems	Distribution Planning	Ref		6												47		
		Transmission Operations	Ref	1	6	9	15	20			31	32				40			51
Categorized as Integration	Building Automation	Distribution Operations	Ref	1	6	9	15	20				32						47	
		Auto-DR	Ref											24		41			
CEC Consumer Category Area	Home Area Networks	Integrated Renewables Control	Ref	2	6	9	15	20					24	38	41				
		Integrated Storage Control	Ref					23	27						38	41			
CEC Distribution Category Area	Feeder & Substation Automation and Communication Systems	Behind the Meter Generation	Ref	3	7	10	16	21					56	39	42				
		PHEV Charging Control	Ref						27				55	54		42			
CEC Distribution Category Area	Substation Storage	Smart Appliances	Ref					21				55	54		42				
		Low Voltage DC Wiring	Ref												60				
CEC Distribution Category Area	Functional Value to Consumer	Incorporate Variability	Ref	4	8	11	17	22											
		Advanced Asset Monitoring	Ref															46	48
CEC Transmission & Distribution Category Area	Electricity Storage	Incorporate BiDirection	Ref	4	8													47	
		Behind the Meter Storage	Ref			12		23	27							43			
CEC Consumer Category Area	Vehicle to Grid (V2G)	Community Distributed Storage	Ref			12		23							43			49	
		Grid Connected Storage for Operations	Ref			12		23		23									53
CEC Consumer Category Area	Functional Value to Consumer	Storage at Large Scale Renewable Generation	Ref			12		24											
		PHEV/Breen/Managed Charging	Ref			13		25	27							44			
Not Categorized by the CEC	Distributed Resources	Meter on the Vehicle	Ref			13		25	27						44				
		Synthetic Inertia / Governor Response	Ref							33	33								53
		BiDirectional Protection	Ref															50	

Cells link to description/gap analyses and to Rankings

R&D Initiative – High Speed Grid Reliability Enhancement

Vision

High Speed Monitoring and Control of Grid to Enhance System Stability and Robustness

Issue

- High RPS alters system dynamics in a fundamental way, especially when fewer conventional generators are on line
 - lack of inertia and governor response, different excitation; different locations of renewables.

Technologies

- Synchrophasors and high speed wide area networks
- Integrated control of high speed system resources (inverter based renewables and large scale fast grid connected storage)

Research & Development

- Grid dynamics under high RPS
 - Definitive studies on stability impacts of high RPS levels
 - Control algorithms and technologies to utilize high speed resources for stabilization
 - Analysis of where to deploy high speed resources
 - Visualization concepts and technologies
 - New algorithms for dynamic grid control and stabilization

Renewables and Dynamic Performance

Vision

Renewables provide dynamic performance to assist in system stability and control

Issue

- Inverter electronics lack inertia, governor response, excitation control for stability

Research & Development

- Power electronics and control algorithms to achieve synthetic excitation stabilization, inertia, governor response
- System performance under high RPS
 - With and without dynamic performance
 - Integration with wide area PMU based stability augmentation

Technologies

- Power electronics and control algorithms
 - Synthetic voltage dynamics, governor response, inertia

Electricity Storage

Vision

Storage is located throughout the electric infrastructure to support renewables penetration in terms of reliability, economics, operations, and deferred capital. Appropriate storage technologies are integrated in light of applications.

Issue

Regulatory Treatment of Storage & Asset Classification
Matching Technologies to Applications
Deployment and Control Strategies Linked to Renewables

Technologies

Market and Operations Analysis and Simulation
Existing and Developing Storage Technologies, Capabilities, and Economics

Research & Development

- Modeling and analysis to determine how much storage is required/necessary to support California renewable goals
- What role will storage play in helping the state achieve zero net energy residential and commercial new construction goals
- What are appropriate regulatory, market, and incentive treatments to encourage storage in support of renewables?
- Identifying the control technologies and algorithms necessary to ensure storage can seamlessly work with Wind, Grid requirements when integrating CA renewables to the electricity grid
- Continued investigation of emission benefits of storage technologies – i.e. Commercial & Industrial uses
- When storage is used in a multi-purpose application (as at a substation) how to allocate costs and benefits for cost recovery?

Distributed Renewable Resources

Vision

Distributed renewables are dispatchable to provide system operations flexibility and are capable of participating in energy markets; allocation of costs and benefits (especially capital deferral) reflects the full value of renewable resources to the grid

Issues

- Requirement needs for dispatchable DG
- Communications
- Controls
- Tariff structures
- Metering
- Integrating advanced inverters

Technologies

- Storage – DG configurations
- Utilizing internet-Wifi for transferring energy information and energy management
- IEDs
- Next Generation inverters
- HAN and BAS with integrated demand response

Research & Development

- Renewable controllability/renewables and storage
- Demonstrating residential solar-storage applications and testing of dispatchable, guaranteed responses.
- Low cost communications and control
- Market protocols for forecasting, scheduling, integration and capacity, metering standards
- Metering strategies and tariff structures that will facilitate increased penetration of renewables, enhanced DR capability and improved ability to achieve statewide zero net energy goals
- Demand forecasting and elasticity R&D

Green Charging

Vision

PHEV and EV owners can enroll in green charging that matches vehicle charging to specific renewable power production and obtain incentives, RECs and tariffs that facilitate enhanced renewable penetration

Issues

- PHEV and EV load is behind the meter
- Currently no separate measurement and control
- PHEV and EV mobility
- Back office billing and settlement

Research & Development

- Vehicle metrology and applications
- Market/rate structures
- Separate settlements process

Technologies

- Wireless Internet and GPS
- Metering on vehicles
- Cloud computing
- HAN with integrated demand response

Flexible Distribution Circuits

Vision

Distribution circuits capable of supporting high RPS will require adaptive protection, automation and the possibility for bidirectional flows and ability to adapt to high variability

Issue

- Current engineering, protection, and operations are non-adaptive and provide for radial flows only

Technologies

- Distribution automation
- Intelligent Electronic Devices
- Substation automation
- Stochastic circuit analysis for planning and operation

Research & Development

- Cost benefit analysis of bidirectional flow
- Analytics for planning and operations
- Software upgrades to field devices (IEDs)
- Communications

Price Responsive Load (Dynamic Pricing or Time Variant Pricing)

Vision

Building Automation Systems (BAS) in commercial buildings and residential Home Area Network (HAN) systems can interact with hourly prices to create demand price elasticity in the markets

Issues

- Lack of market protocols
- Difficulties in forecasting
- Lack of BAS / HAN applications support
- Communications and Settlements
- Rate Structures
- Device Compatibility and Interoperability

Technologies

- Internet
- Device Networking
- Local optimization devices

Research & Development

- Econometrics and forecasting
- Market structures and mechanisms
- Elasticity metrics
- Optimization strategies
- Time Variant pricing strategies to harness power of distributed generation resources
- Uniform definitions of device object and attributes and binding rules

Home Automation Networks and DC Power Distribution

Vision

Future Zero Net Energy Buildings will have low voltage DC wiring linked to Distributed Renewable generation and storage – role of 120/240 V AC is limited to grid interconnection

Issues

- Eliminate conversion losses and stand-by demand
- More “natural” for distributed renewables
- Lack of standards for commercial lighting / electronics today

Technologies

- LED Lighting
- Solid state low voltage protection / controls
- Electronics with standard DC supplies

Research & Development

- Standards (UL, Building Code, electronics industry)
- Cost benefit analysis considering future electronics products and pricing and any new / existing construction costs
- DC motor and drives in larger appliances
- Transition of HAN communications to DC wiring base, Low Voltage DC PLC
- Embedded revenue grade metering and home area network connectivity in large appliances
- Software defined radios and agile frequency transceivers for HAN Gateways

Prioritizing R&D Objectives

- KEMA Assessment Provides a First Pass at Prioritization
- Stakeholder Workshops Utilizing the Matrix Artifact a Possibility
 - Prioritize Renewable Facilitation Objectives
 - Prioritize Impacts of Smart Grid Tactics on Facilitation Objectives
 - Prioritize Impacts of Smart Technologies on Tactics
 - Compute Technology Rankings as Prioritization