Utilities of the future

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Madrid, 2-3 July 2014
Contents

• Research focus
• From technologies to business models
• Analytical models
• Future research
Context: “Utility of the future” project

- A MIT and IIT-Comillas research team
- Focus: “analyze the future of the delivery of services that electricity can provide, either in a centralized or decentralized manner, identifying successful business models, regulatory trends and transformative technologies, within the global framework of an increasingly decarbonized power sector.”
Centralized vs decentralized resources

- Limited interconnections
- Big power generation plants
- Technically optimized to fit local demand
- Regulatory deficiencies in commercial framework
- Outdated technology (more than 100 years old)

Policy drivers for transformation

- Transition towards a low-carbon economy
- EU Energy policies
  - Support to renewable and CHP production
  - Energy efficiency action plans
  - R&D and D&D projects for smart grids
- US State regulatory commissions: plans to integrate more DER and reform regulatory models

CAPUC: Assembly Bill No. 327

HIPUC: “Inclinations on the Future of Hawaii’s Electric Utilities”

MADPU: Grid Modernization Proceedings

NYPSC: “Reforming the Energy Vision”
Technology drivers

- Information and communication technologies

- Distributed energy resources
  - Flexible demand (demand response): smart meters, building and home EMS, virtual storage
  - Distributed on-site generation: PV, CHP, biogas, back-up units
  - Plug-in electric vehicles (dumb and smart charging, V2G)
  - Power storage: batteries
  - Power electronics and control for integration of resources

- Converging infrastructures: energy (electricity, gas, heat), transportation, communications (smart cities)
Socio-economic drivers

- Sustainability
- Self-sufficiency
- Affordability
- Self-governance
- Example: The rise of the personal power plant (IEEE spectrum)

“Smart and agile power systems will let every home and business generate, store, and share electricity”
System-wide impacts

• If the provision of electricity services becomes more diverse and decentralized (in a fundamental and sustainable manner)

• Greater competition for centralized generators
• Changes to transmission and distribution system investment and operation
• Changes in energy mix, with implications for climate change
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From technologies to business models
Services provided by business models

- Service categories provided by business models to end-users
  - Capacity / peak demand reduction
  - Energy / self-generation and exports
  - Resilience against grid outages
  - Multi-energy services

<table>
<thead>
<tr>
<th>Business Model Attributes</th>
<th>Own</th>
<th>Operate</th>
<th>Finance</th>
<th>Build</th>
<th>Aggregate</th>
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Solar City-Tesla: PV installer/car-battery maker
NRG Beacon 10: solar-natural gas-battery: 15 kW of electricity + heat + hot water
Stem: batteries networked with EMS
Coda Energy: renewable + batteries reducing building energy bills
Aggregator business model

- DSS: Decision Support System
- EB: Energy Box
- WSN: Wireless Sensor Network
- S: Sensor
- A: Actuator
- RS: Remote Sensor
- RA: Remote Actuator
- CHCP: Combined Heat Cold & Power
- CHP: Combined Heat & Power
- VSC: Back to Back Voltage Source
- ECU: Electronic Control Unit
- PV: Photovoltaic panels

Electronic device
Generator
Renewable generator
Load

Power Grid

Prosumers

Aggregation Management System

Service Portal
Data Model
Optimization & prediction

Communications

VSC: Back to Back Voltage Source
ECU: Electronic Control Unit
PV: Photovoltaic panels
CHP: Combined Heat & Power
CHCP: Combined Heat Cold & Power

Prosumers

Aggregator

EB
S
RS
RA

Systems

DSS
A
S

Utilities of the future
2-3 July 2014
Business Model Analysis: Framework

Fundamentally, we want to understand how various business models can meet the needs of various electricity industry actors.

Available technologies

Technological Capabilities

Executional & Operational Capabilities

Cost-Benefit Analysis

Services: {Quantity, Cost}

Revenues

Costs

Sociotechnical Context:
energy & environmental policies; interactions with other key sectors

Regulatory environment

Market Rules

Value:

\[ f(C_i, S_j^*, N_m) \]

Needs:
{Quantity, Willingness To Pay}

Customer
(Residential, Commercial, Industrial, DSO, TSO, etc.)

\[ h(\text{Value}) \]

\[ g(\text{Value}) \]
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Analytical models

Technologies

Business Models

End User Models
Levels I & II

System-wide impacts
Level III

End User energy dispatch

End User as service provider

End User investment decision-making

Generation / Wholesale market models

System Operation Transmission models

Distribution grid models
Distributed energy resources – Customer adoption model (DER-CAM)

**Inputs:**
- Building end-use load data
- Electricity & gas tariff data
- DER technology data
- Site weather data

**Objectives:**
- Minimize total cost
- Minimize CO₂ emissions

**Outputs:**
- Optimal DER capacities
- Optimal DER operations schedule

- **Investment & Planning:** determines optimal equipment combination and operation based on historic load data, weather, and tariffs
- **Operations:** determines optimal week-ahead scheduling for installed equipment and forecasted loads, weather and tariffs
Optimal schedule of resources: An example

- End User (building) energy bill minimization

DER-CAM minimizes on-peak purchases due to high demand charge
Large-scale distribution grids planning - Reference Network Models

Network structure and simultaneity factors

Type of facilities

- Transmission substations
  - (36,220) kV
  - (1,36) kV
  - <1 kV
  - LV customers

- HV/MV substations
- MV/LV transformers
- HV customers
- MV customers
- LV customers

• Input Data: HV, MV and LV customers, and transmission substations
• Results of the model: LV, MV & HV network, HV/MV and MV/LV substations
DG penetration (RNM): Netherlands - Kop van Noord

- Rural/sub-urban area
- Approx. 80,000 loads (~675 km²)
- Grid: HV (150kV-50kV) and MV (10kV)
- LV loads aggregated at MV points
- Present DG already high in relation to local demand
- Major developments expected in DG (especially at MV):
  - Attractive area for further growth of wind energy
  - Mayor developments in agriculture: CHP for horticultural greenhouses
Grid investment planning with increasing DG (RNM)

- 2020 DG scenarios: Netherlands - Kop van Noord

Present value of investment and maintenance costs

Plug-in electric vehicles – PEV Aggregator (PEVAGG)

Electricity Market - PEV Aggregator
- Takes market decisions on multiple trading floors
- Exposed to uncertainty in prices, fleet availability and demand

MV/LV Distribution Grid - DSO
- Network expansion planning
- Operates the grid in secure conditions (voltages, line currents)
- Calculates network use-of-system fees

PEV Mobility - Final customers
- Drive and connect at supply points
- Require energy for mobility
System-wide impacts of distributed resources (ROM)

- Reliability and operation model of generation/wholesale
- Simulation of system operation with integration of renewables
- Effects of large penetration of distributed resources: e.g. demand flexibility

RESULTS

- Operation
  - Output of different technologies (thermal, hydro, pumped hydro)
  - Fuel consumption
  - Primary energy (wind or hydro) surplus
- Emissions
  - Carbon emissions
- System reliability
  - EENS (Expected Energy Not Served)
  - LOLP (Loss of Load Probability)
  - LOLE (Loss of Load Expectation)
  - XLOL (eXpected Loss Of Load)
- System Marginal Costs
ROM: demand shifting (cost minimization)

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Major implications

• If provision of electricity services becomes **increasingly diverse and decentralized**, it has important implications for a number of interrelated issues:
  
  • **Climate**: future generation mix, policy and regulatory environment
  • **Economy**: societal/economic benefits of a more decentralized system
  • **Policy**: trade-off between short and long-term roadmaps and continuous adaptation to new situations and environments
  • **Regulation**: Regulation and markets may need to be reformed to create a level playing field of new electricity services and products
  • **Technology**: New technologies and operational paradigms can emerge in a distributed future
  • **Industrial Organization**: The electric power industry could change dramatically as new players and organizations reshape the way electricity services are delivered
The MIT Utility of the Future Study

Research tasks

1: Candidates & Tools
- Identify Existing & Develop Improved Regulatory Frameworks
- Develop & Adapt Analytical Models
- Identify & Classify New Candidate Value Propositions
- Game changing technologies
- Screen available news & reports
- Brainstorm/think / expert scan

2: Evaluation
- Techno-Economic-Regulatory Assessment

3: Implications
- Power Sector as seen from: gas; transport; ICT; buildings; other sectors
- Implications for the Status Quo: markets, system operators, industry structure, regulations
- Strategies available to incumbent utilities

4: Outcomes
- Scenarios for Utility Sector of the Future
- Findings for Regulators & Policy Makers
- Findings for Incumbent Utilities
- Findings for New Business Models
Major Questions

• What new business models (BMs) could succeed?
  o Which factors determine success & failure?

• How these BMs could complement / compete with / add to the services provided by the incumbent utilities?
  o How much could these BMs penetrate?

• How other sectors (gas, ICT, buildings, transportation) could be affected / participate in this transformation?

• What major shortcomings exist in current regulation to be taken advantage of by BMs?
  o How to fix them to create a level playing field?

• What are some realistic scenarios of the delivery of electricity services in 2025?
Thank you for your attention !!!

“Utility of the Future” Project Team:
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