Co-construction methodologies and EMS applications in microgrids

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Agenda

- Co-construction methodology
- EMS
- Resilience capability
- Conclusions and challenges
Co-construction scheme
(Open-framework for microgrid development)

Stage 1
- SOCIOTECHNICAL DIAGNOSTICS AND TEAM FORMATION

Stage 2
- DESIGN OF THE SOCIOTECHNICAL SYSTEM AND SUSTAINABILITY PLAN

Stage 3
- IMPLEMENTATION AND COMMISSIONING

Stage 4
- OPERATION, EVALUATION AND DISSEMINATION
Methodology: Stage 1

Stage 1

0. Team Formation
1. Gathering information
2. Training / preliminary discussion of alternatives
3. Training / preliminary discussion of alternatives
4. Discussion of alternatives
5. Presentation and discussion of preliminary results
Methodology: Stage 2

Technology cost

Optimum design tool

Storage 300kWh

Diesel 70kW

Wind 30kW
Methodology: Stage 2
Methodology: Stage 2

- Sustainability indicators
- Energy rates / payment!
- Operation and Maintenance
- Local Management Structure
- Communications channels
Methodology: Stage 3

Huatacondo
Isolated community - 30 families

Nov 2009 - Begining
Sep 2010 - Launching
2011 - 2015 - O&M
Methodology: Stage 3

- GenSet: 120kVA
- BESS: 40kW-140kWh
- Main PV: 22.5 kW
- Wind: 3kW
- Sec. PV: 3kW

Load: 30 houses

Water tank: 2HP / 6kL

Power diagram
Methodology: Stage 4

Day: 2014-07-11

- GenSet
- Eolico
- PVs
- INV-BAT
- Dda

Graph showing power output over time with various stages.

Stage 4: Methodology

Storage: SOC

- 100% Discharge
- 20% Charge
- 80% Discharge
- 50% Charge
Methodology: Stage 4

- PV tracking system
- 2 linear actuators
- No sensors
- Centralized control
- Position feedback
- Intelligent relay local control
- Mechanical constraints considered on EMS
Methodology: Stage 4

E-Waste in 2007
(Source: EPA, 2007)

- Televisions
- Computer Products
- Cell Phones

Millions of units

- Recycled
- Trashed

Micro-formers

Stage 1: Sociotechnical Diagnostics and Team Formation
Stage 2: Design of the Sociotechnical System and Sustainability Plan
Stage 3: Implementation and Commissioning
Stage 4: Operation, Evaluation and Dissemination
Methodology: Stage 4

Micro-formers

Low voltage transmission

Pros
- Easy to build
- No transformers needed
- Consumers and producers easily connected

Cons
- Expensive, thick copper wire
- High distribution losses, low efficiency
- 100 meter range

Quality:  
Cost:  
Efficiency:

High voltage transmission

Pros
- Low distribution losses, high efficiency
- Thin wire
- High power capacity (typical)
- 10 to 100 km range

Cons
- Expensive, bulky transformers
- Expensive poles
- Added complexity in connecting consumers and producers

Quality:  
Cost:  
Efficiency:

Microformer transmission

Pros
- Easy, low-cost construction
- Consumers and producers easily connected
- Low system losses, average to high efficiency

Cons
- Modest amounts of power
- 1 to 5 km range

Quality:  
Cost:  
Efficiency:
Methodology: Stage 4

Social SCADA

- Interface Design
- EMS Communication
- Design of Indicators
Methodology: Stage 4

Social SCADA
Methodology: Stage 4
Methodology: Stage 4
Agenda

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- EMS
- Resilience capability
- Conclusions and challenges
Proposed EMS – Rolling Horizon

Inputs
- Maximum and minimum available solar power ($P_{S_{\text{max}}}, P_{S_{\text{min}}}$), wind power ($P_{E}$), load profile ($P_{L}$), water consumption ($w_{c}$), initial conditions for the battery charge ($E_{\text{SOC}_{i}}$), battery bank voltage ($V_{i}$) and current ($I_{i}$), water tank level ($V_{Ti}$) and diesel on/off state ($B_{gi}$).
- Power references for the diesel ($P_{D}$) generator, the ESS inverter power ($P_{I}$), the binary signals for the water supply system ($B_{P}$), the desired solar power ($P_{S}$) and the signals for loads ($S_{L}$).

Outputs

Energy Management System Framework

Optimal operation:
- EMS: Unit commitment + Economic Dispatch
Energy Management System

\[ J = \delta_t \sum_{t=1}^{T} C(t) + \sum_{t=1}^{T} C_s(t) + C_{US} \delta_t \sum_{t=1}^{T} P_{US}(t) + C_{Tf} \sum_{t=1}^{T} V_{Tf}(t) + C_H(T) \]

- Diesel variable costs
- Start-up diesel costs
- Penalization of the unsupplied energy
- Penalization of the unserved water supply
- BESS lifetime penalization

Diagram showing a network with different energy sources and storage systems.
Modeling of Conventional Units

\[ q(t) = \sum_{v=1}^{n_v} \left( \alpha_v P_v(t) + \beta_v B_v(t) \right) \]

\[ B_g(t) = \sum_{v=1}^{n_v} B_v(t) \leq 1 \quad P_D(t) = \sum_{v=1}^{n_v} P_v(t) \]

\[ P_{v_{\text{min}}} B_v(t) \leq P_v(t) \leq P_{v_{\text{max}}} B_v(t), \quad v = 1, ..., n_v \]

— Start-up costs

\[ C_s(t) \geq C_D(B_g(t) - B_{g0}) \quad t = 1 \quad C_s(t) \geq 0 \]

\[ C_s(t) \geq C_D(B_g(t) - B_g(t-1)) \quad t > 1 \]
Control system

Measurement and control
Control software

.NET application -> “Operación Huatacondo”

Control and monitoring per unit
Control software

.NET application-> “Operación Huatacondo”

μGrid monitoring and control
Control software

EMS Software

General configuration:
- DBs
- Optimization parameters
- DSM parameters

BESS configuration:
- Load curve
- Pmax, Cap (Ah), Efficiency

GenSet configuration:
- Consumption curve
- Pmax, Pmin
- Star-up costs, Diesel
- Operational constraints
- Diesel fuel storage
Control Issues

EMS set points → operation mode diagram for Huatacondo

Additional issues:
- Solar panel, wind always non-dispatchable
- Pump independent of state
Control Issues

Operation mode examples
Continuous optimal control approaches to microgrid energy management

Benjamin Heymann\textsuperscript{1} - J. Frédéric Bonnans\textsuperscript{1} - Pierre Martinon\textsuperscript{1} - Francisco J. Silva\textsuperscript{2} - Fernando Lanas\textsuperscript{3} - Guillermo Jiménez-Estévez\textsuperscript{3}

\[
\begin{align*}
\text{(OCP)} & : \\
\min_u & \int_0^T \ell(u(t)) dt + g(x(T)) \\
\dot{x}(t) & = F(u(t), t) \\
x(0) & = x_0 \\
u(t) & \in U_{x(t)} \\
x(t) & \in \mathcal{C}.
\end{align*}
\]

\[
S\hat{\text{O}}C(t) = \frac{1}{Q_B} (P_I(t)\rho_I - P_O(t)/\rho_O),
\]

\[
P_D + P_O + P_S + P_{\text{slack}} - P_L - P_I = 0.
\]

\[
\int_0^T KP_D(t)^{0.9} dt,
\]
Other EMS approaches

Rule based EMS

Microgrid operation with solar power spill (real performance)
### Other EMS approaches

#### Rule based EMS

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<th>Real performance</th>
<th>HOMER simulation</th>
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<tr>
<td>PV production [kWh]</td>
<td>316.997</td>
<td>447.764</td>
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<td>Wind production [kWh]</td>
<td>29.538</td>
<td>50.905</td>
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<td>Diesel based production [kWh]</td>
<td>360.875</td>
<td>157.366</td>
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<td>Renewable fraction of consumption [%]</td>
<td>48.9</td>
<td>71.6</td>
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<td>Diesel consumption [lt]</td>
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<td>40.872</td>
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<tr>
<td>Non Served Energy [%]</td>
<td>-</td>
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</tr>
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#### New Rules → Homer

**Summer**

SoC [%]

**Autumn**

SoC [%]
Agenda

• Co-construction methodology

• EMS

• Resilience capability

• Conclusions and challenges
Microgrids – Resilience capability

Resilient microgrid:
i) withstand technical, social, economic, and/or natural hazards without losing its functionality,
ii) if it is impossible to keep full functionality, keep a minimum level of supply to assure the supply of crucial load and to facilitate the potential recovery, and
iii) recover its operating conditions previous to the occurrence of the disturbance. Thus, a resilient microgrid maintains its functionalities as best as possible before, during, and after a disturbance.

Microgrids - Huatacondo

2012 Venida:

2014 Storm

2014 IQQ Earthquake:
Other experiences

Ollagüe microgrid: microgrid diagram (left) and black start capability (right).
Other experiences

Puertecitos microgrid operation: low demand scenario (left) and high demand scenario (right)
Grid Connected

What we have to date?

**Law 20.571**: Net Billing scheme → rules and technical standard (up to 100 kW)

Source: Energy Ministry
Grid Connected

What we have to date?

Smart Meters

55,000 smart meters in Santiago

500 aggregators

BIG DATA !!
Multiple users → multiple interests
Pilot project – Arica (Emergency- Resilience)

Arica city emergency map (left side), tsunami flood areas (blue area), meeting points (green points) and escape routes (black). Selected area for the first stage (right side)
Grid Connected

Operation of multiple microgrids

Grid Connected

One feasible way!

Conclusions

Distribution system is facing many challenges, a new environment is no longer the cable+pole industry.

Consumers are looking for new products, tariffs, and self generation → prosumers.

Reliability, flexibility and resilience to be improved under this new scenario.

DER integration and smart metering one of the first steps in this path.

Microgrids appear as a proper technological + social tool to cover these challenges.

Microgrids → not only DER integration but a higher reliability and resilience capability.

How do we design a regulatory framework to deal with these issues → transition stage as first step.

Value of co-construction methodologies → resilient socio technical systems.
Resiliencia, flexibilidad y sostenibilidad

Contacto

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