Co-construction methodologies and EMS applications in microgrids

Dr. Guillermo Jiménez Estévez, Rodrigo Palma Behnke
Patricio Mendoza, Marcia Montedonico, Lorenzo Reyes,
Bernardo Severino, Ignacio Polanco, Felipe Valencia

Centro de Energía FCFM
Universidad de Chile

CENTRO DE ENERGÍA

FACULTAD DE CIENCIAS FÍSICAS Y MATEMÁTICAS UNIVERSIDAD DE CHILE

Agenda

- Co-construction methodology
- EMS
- Resilience capability
- Conclusions and challenges

Methodology

Co-construction scheme

(Open-framework for microgrid development)

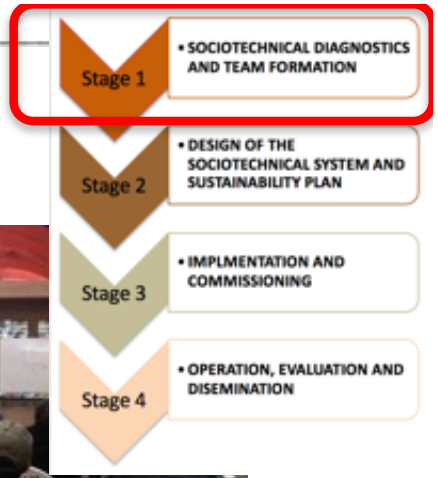
Stage 1
- **SOCIOTECHNICAL DIAGNOSTICS AND TEAM FORMATION**

Stage 2
- **DESIGN OF THE SOCIOTECHNICAL SYSTEM AND SUSTAINABILITY PLAN**

Stage 3
- **IMPLMENTATION AND COMMISSIONING**

Stage 4
- **OPERATION, EVALUATION AND DISEMINATION**

Methodology: Stage 1



Team Formation

Gathering information

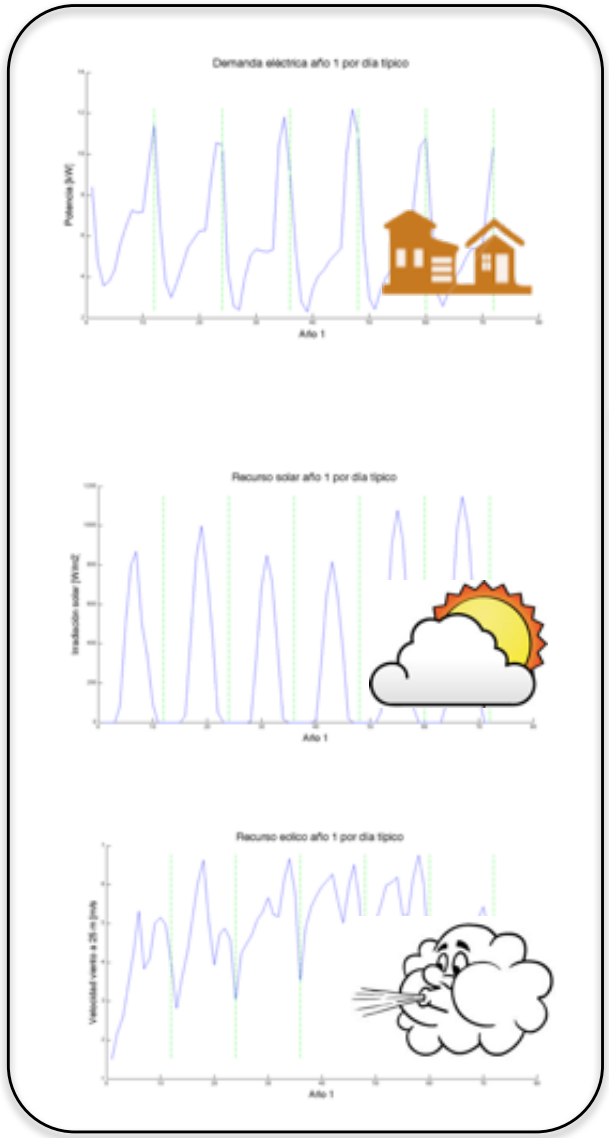
Training / preliminary discussion of alternatives

Training / preliminary discussion of alternatives

Discussion of alternatives

Presentation and discussion of preliminary results

Methodology: Stage 2

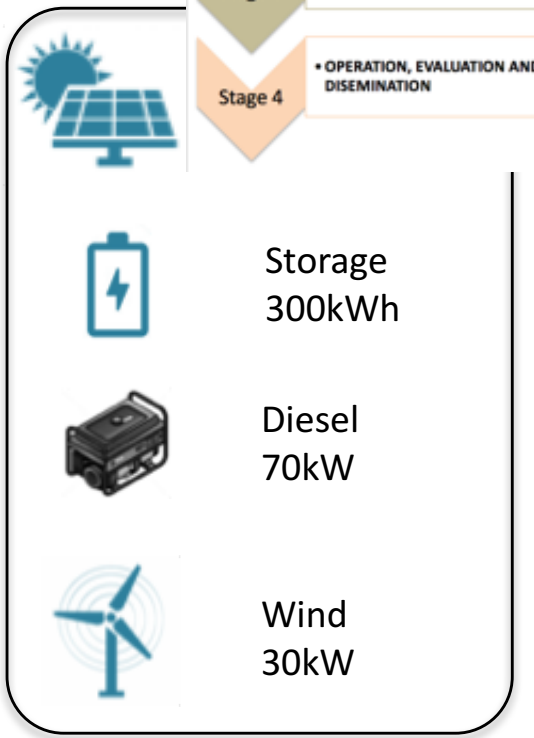


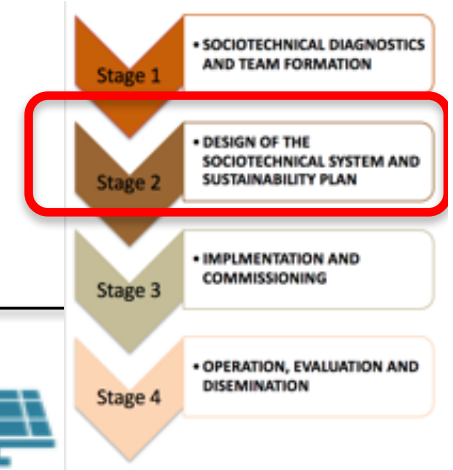
Technology cost

Optimun design tool

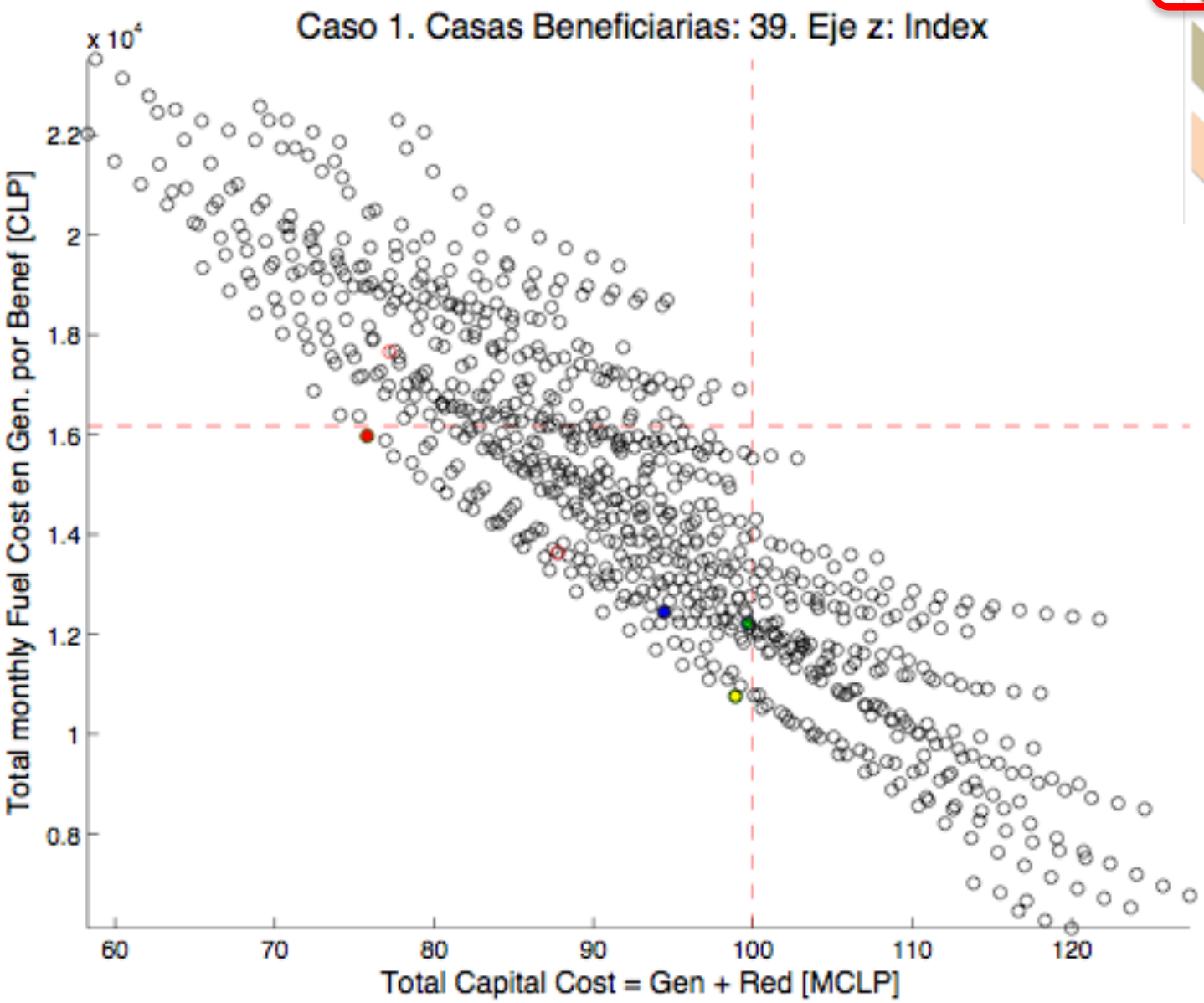
$$\min_{\{E_0,\ I_m,\ P_{m,a,d,h}\}} \quad VAC_P + VAC_W + VAC_B + VAC_G$$

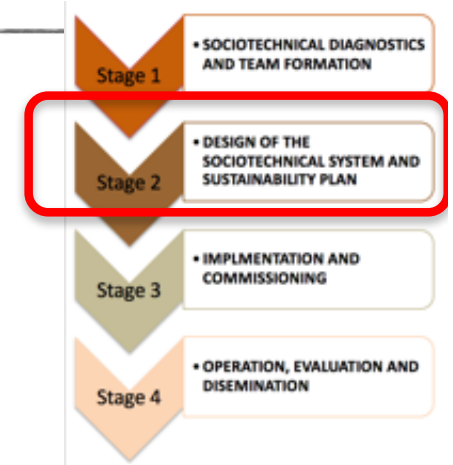
Límites de potencia por unidad	$0 \le P_{m,a,d,h} \le I_m \quad m = \{P, W, G\}$ $P_{BMIN} \le P_{B,a,d,h} \le P_{BMAX}$
Límite de energía en las Baterías	$SoC_{min} \cdot E_{max} \le E_{B,a,d,h} \le E_{max}$ $SoC_{min} \cdot E_{max} \le E_{B,0} \le E_{max}$
Suministrar potencia Dda	$P_{D,a,d,h} = \sum_{m=\{P,W,G,B\}} P_{m,a,d,h} \quad \forall a,d,h$
Potencia aerogenerador	$P_{W,a,d,h} = F\left(W_{a,d,h} \cdot \left(\frac{aT}{aD}\right)^k\right)$
Potencia planta fotovoltaica	$P_{P,a,d,h} = cP \cdot G_{a,d,h}$
Ciclo energético bat. nulo	$\sum_{h=1}^{nH} E_{B,a,d,h} = 0 \quad \forall a,d$
Modelo Baterías 	$E_{BMAX} = H_{nom} \cdot I_B$ $P_{BMAX} = k_{des} \cdot I_B$ $P_{BMIN} = k_{car} \cdot I_B$ $E_{B,a,d,h} = E_{B,a,d,h-1} - P_{B,a,d,h} \cdot nB$



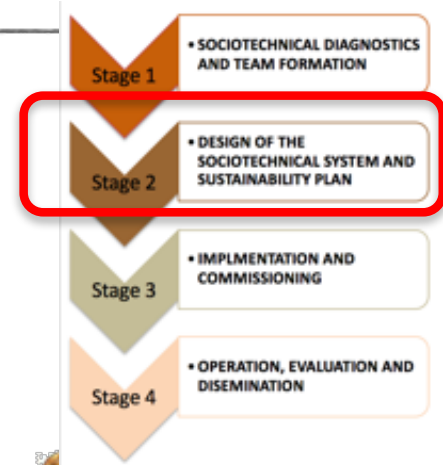


Methodology: Stage 2





Methodology: Stage 2



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

Methodology: Stage 3

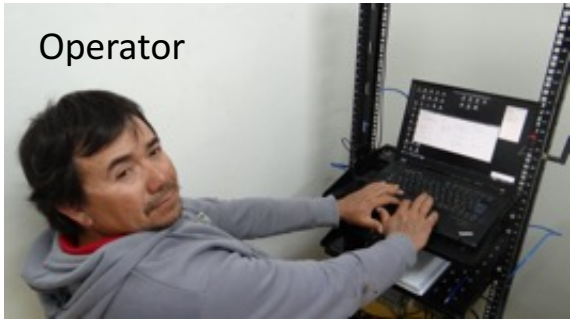
Huatacondo

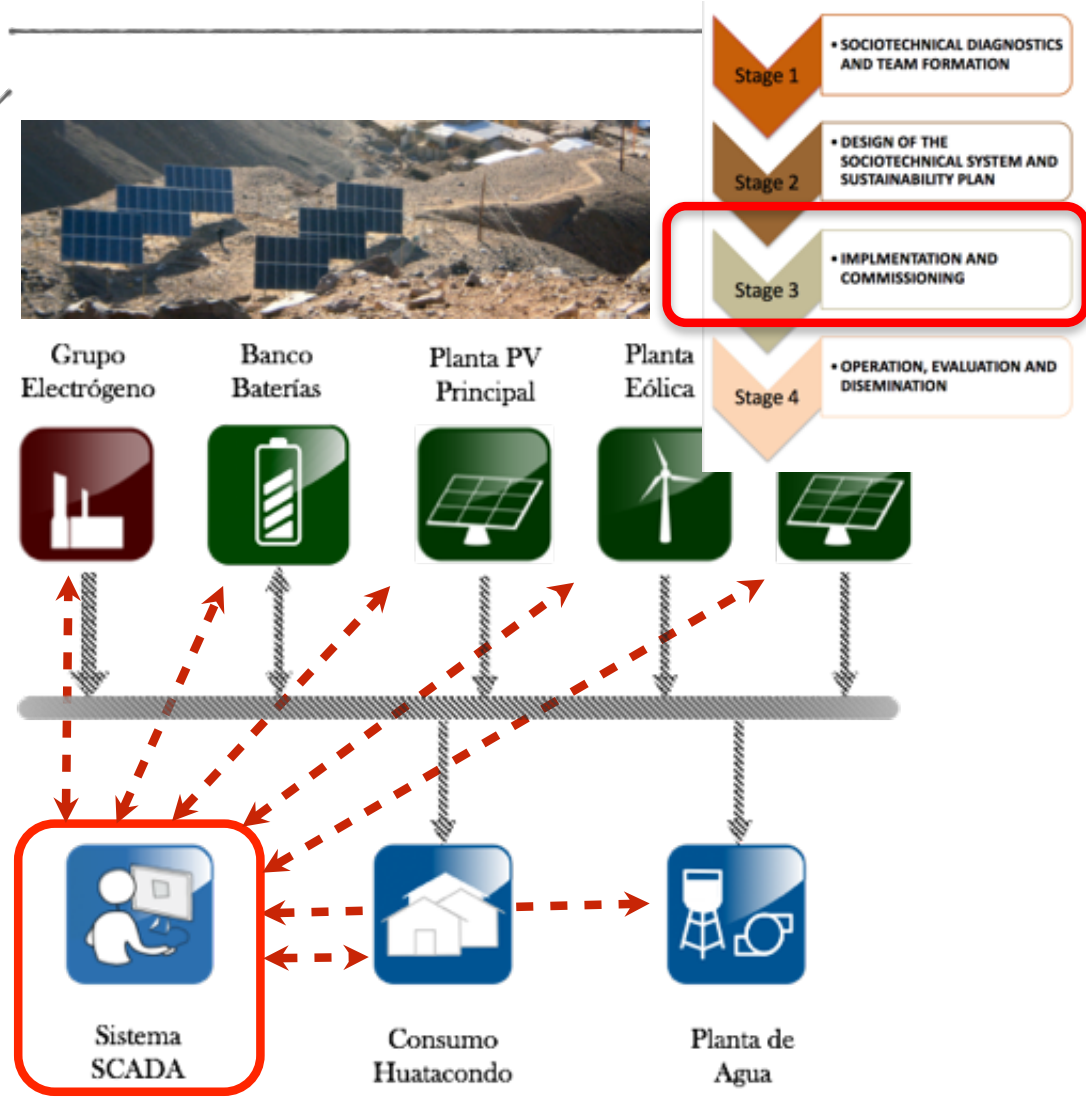
Isolated community- 30 families

Nov 2009 - Begining

Sep 2010 - Launching

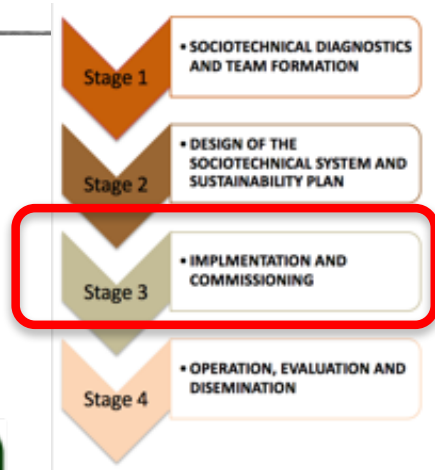
2011 - 2015 - O&M

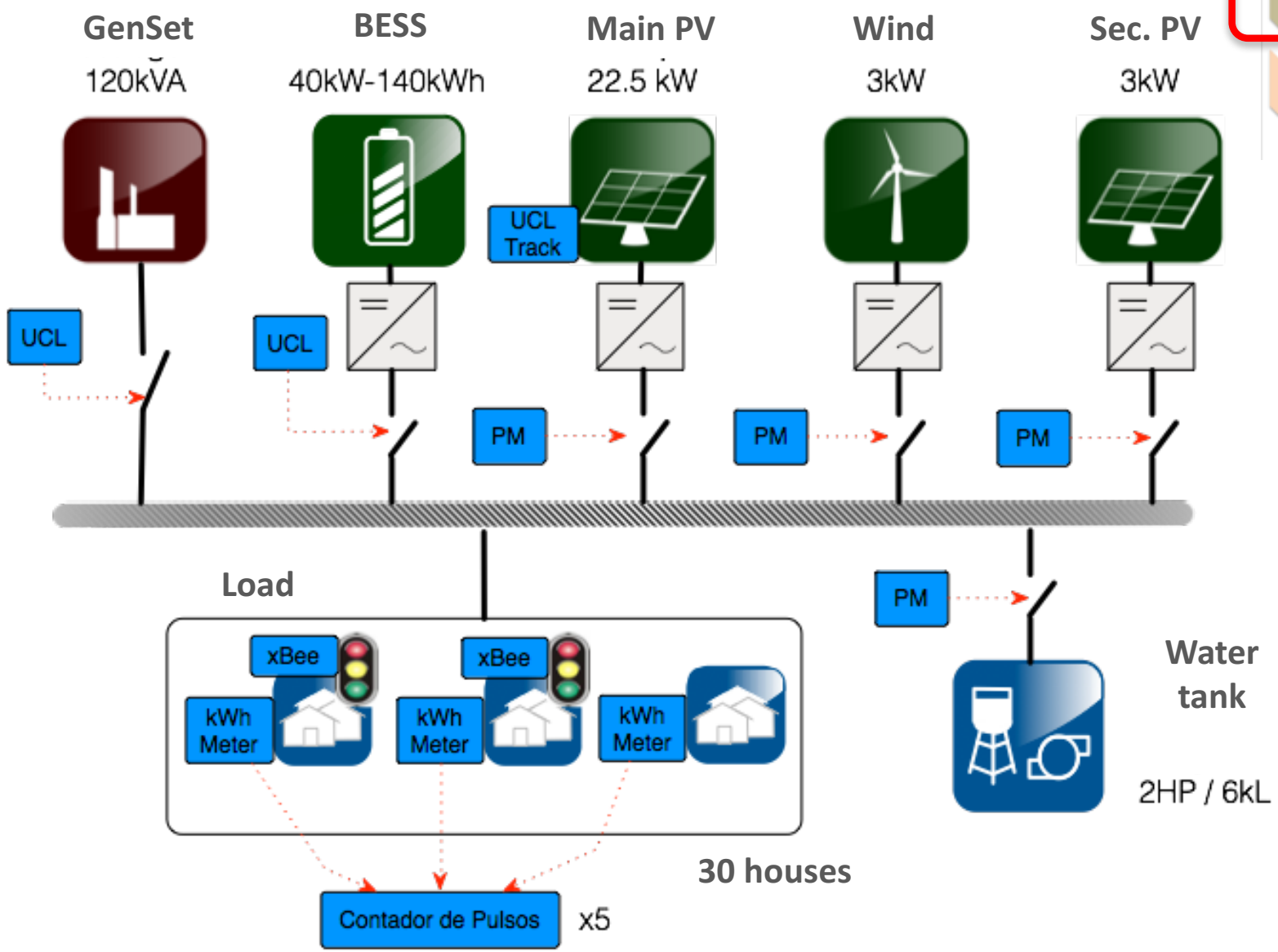




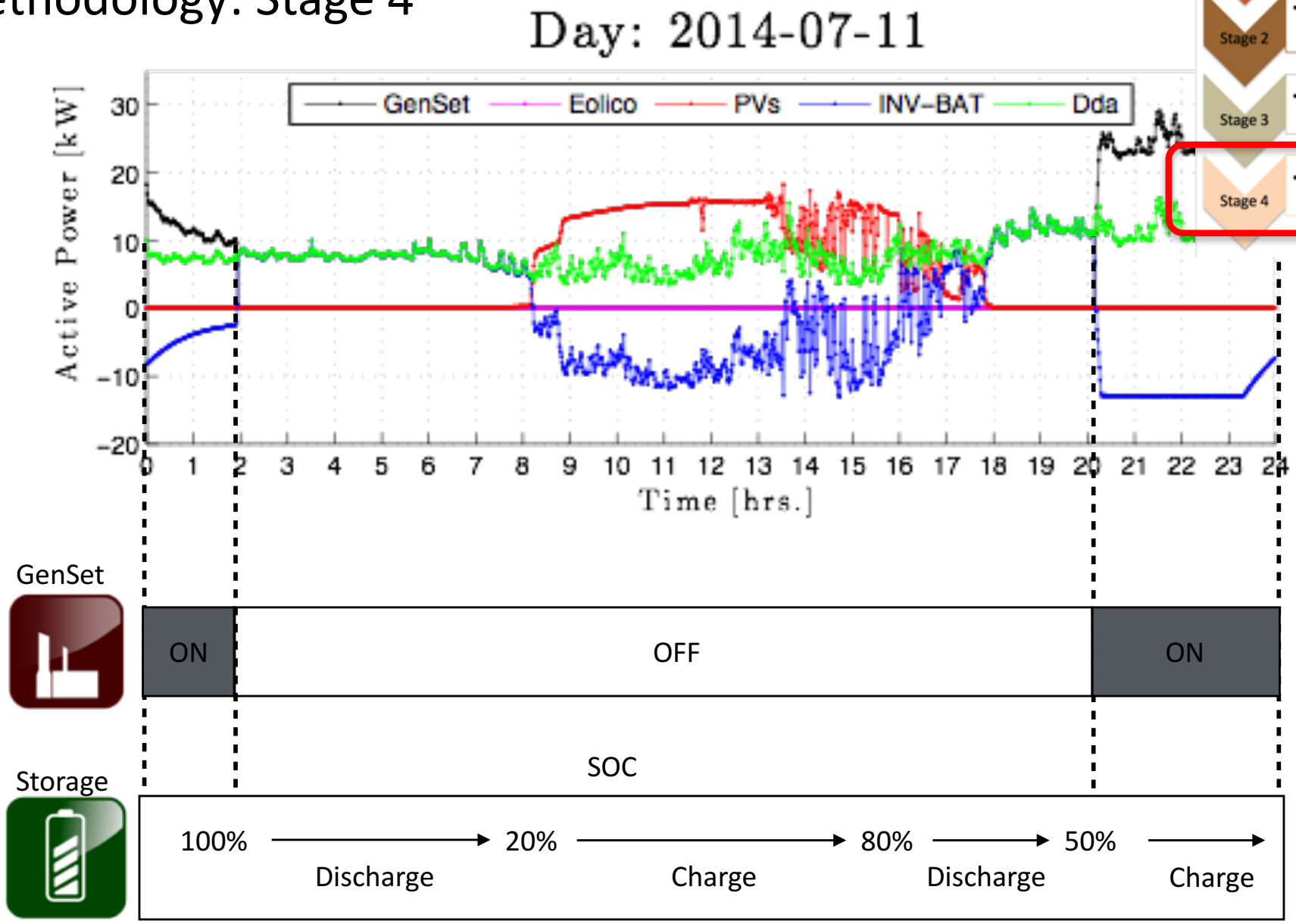
Methodology: Stage 3

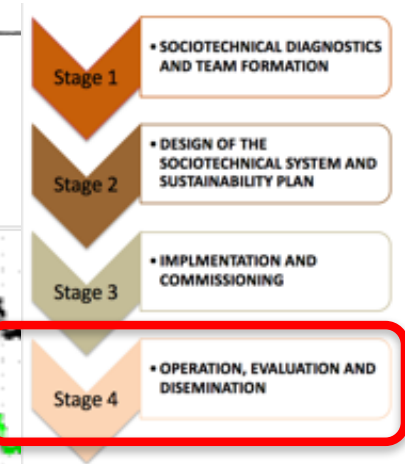
Power diagram





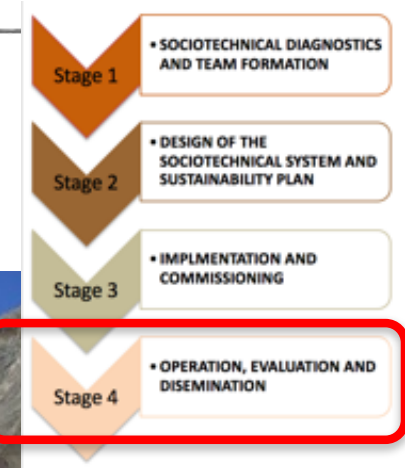
Methodology: Stage 4



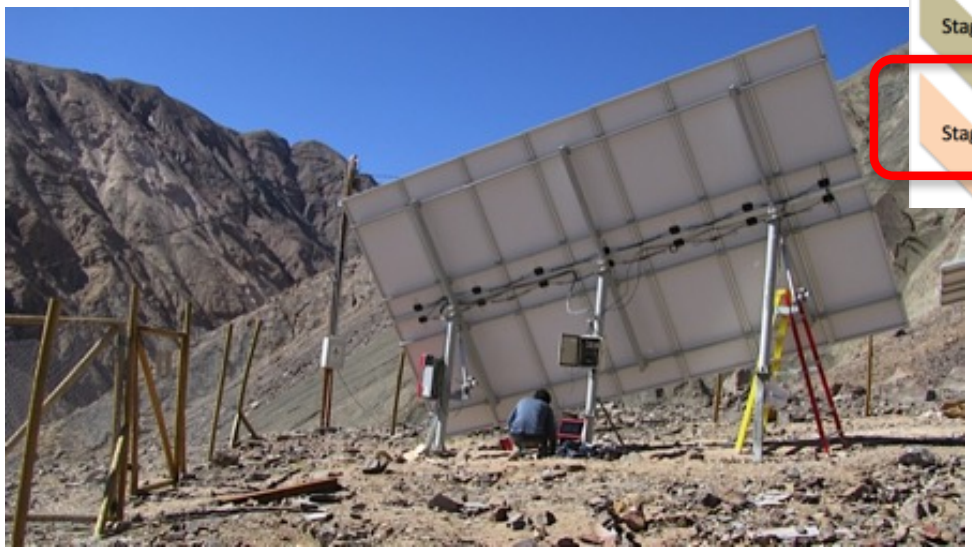


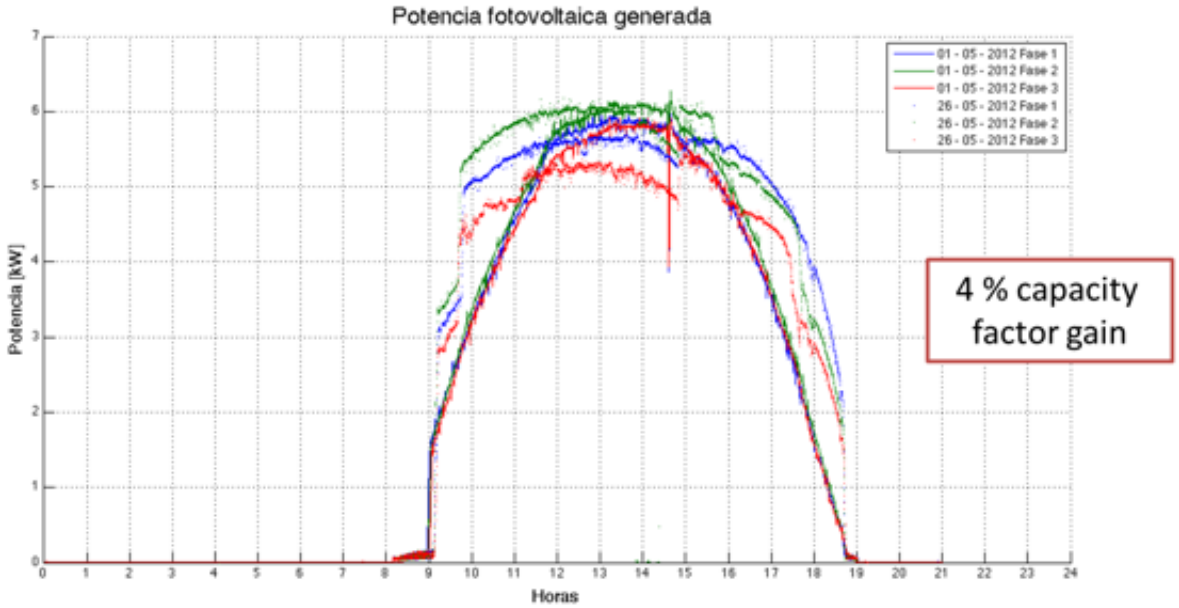
Methodology: Stage 4

PV tracking system



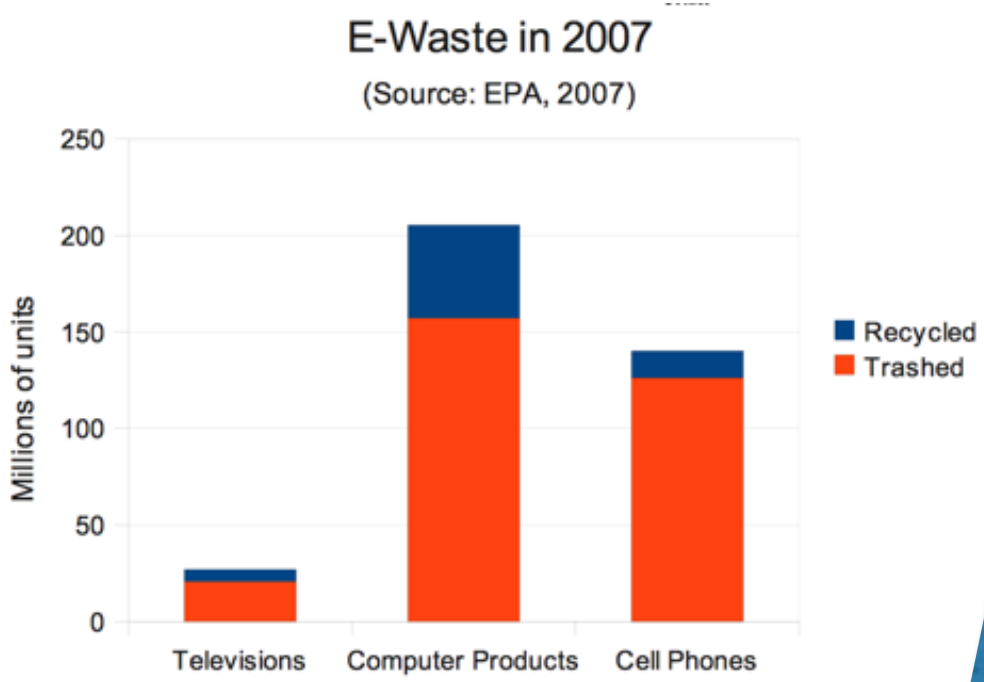
- 2 linear actuators
- No sensors
- Centralized control
- Position feedback
- Intelligent relay local control
- Mechanical constraints considered on EMS

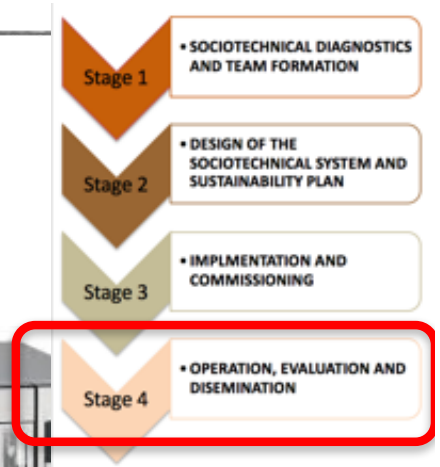




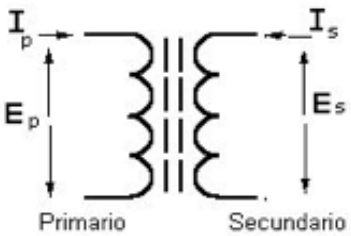
Methodology: Stage 4

Micro-formers





Methodology: Stage 4



Micro-formers

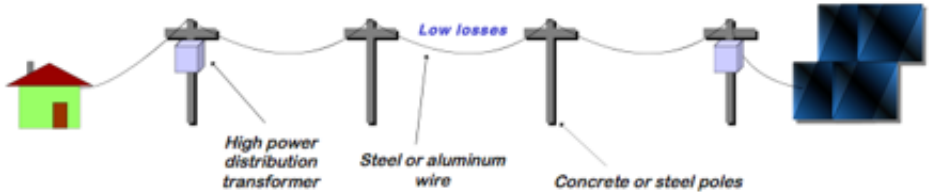
Low voltage transmission

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

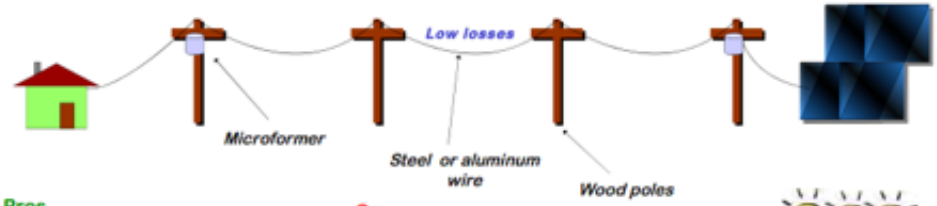


Pros
- Low distribution losses, high efficiency
- Thin wire
- High power capacity (typical)
- 10 to 100 km range

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

Quality:
Cost:
Efficiency:

Microformer transmission



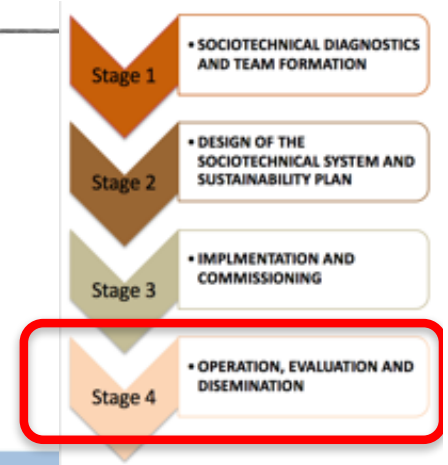
Pros
- Easy, low-cost construction
- Consumers and producers easily connected
- Low system losses, average to high efficiency

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

Quality:
Cost:
Efficiency:

Methodology: Stage 4

Social SCADA



Social SCADA

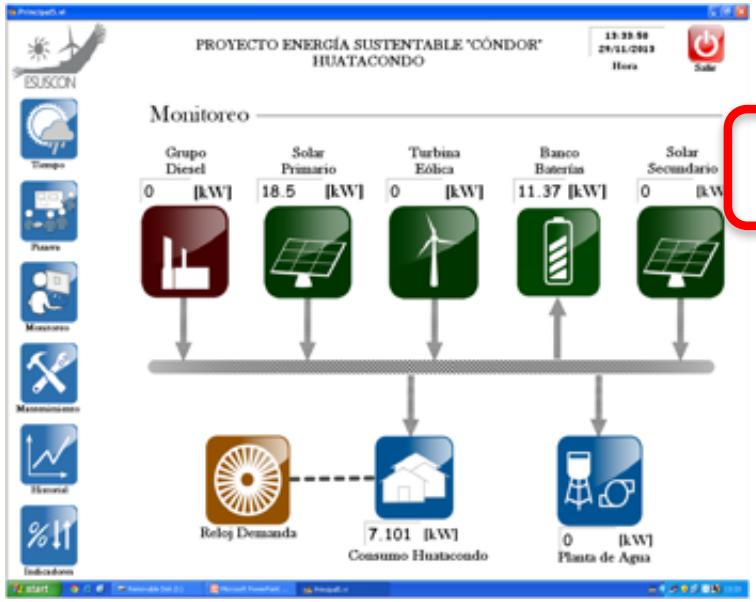
Interface Design

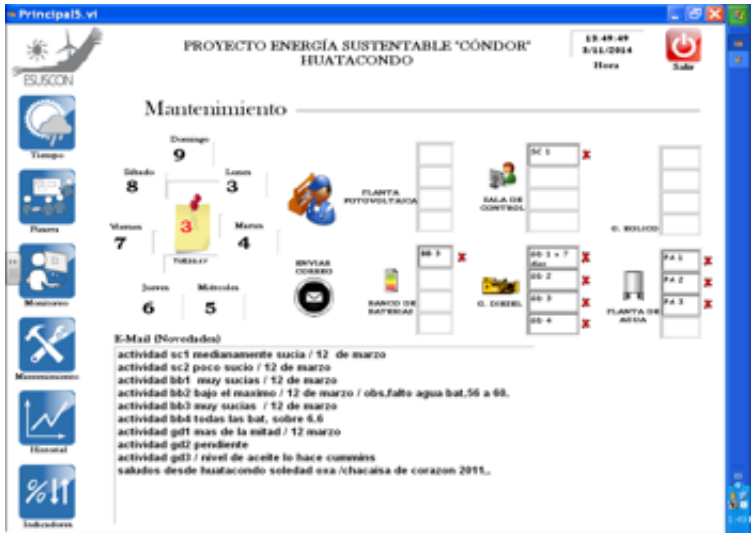
EMS Communication

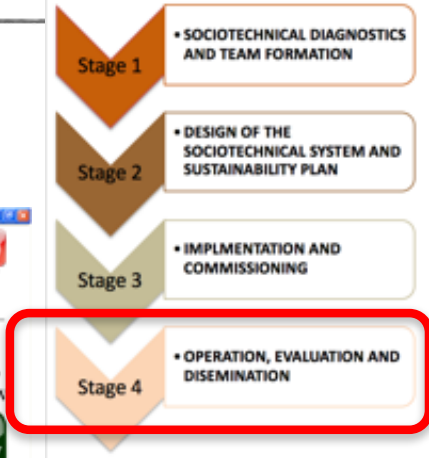
Design of Indicators

Methodology: Stage 4

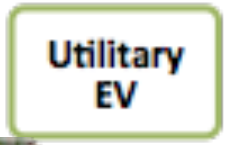
Social SCADA

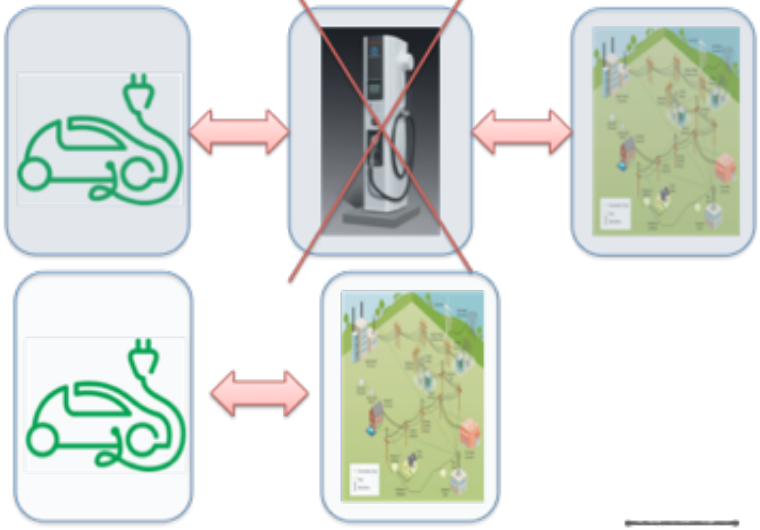




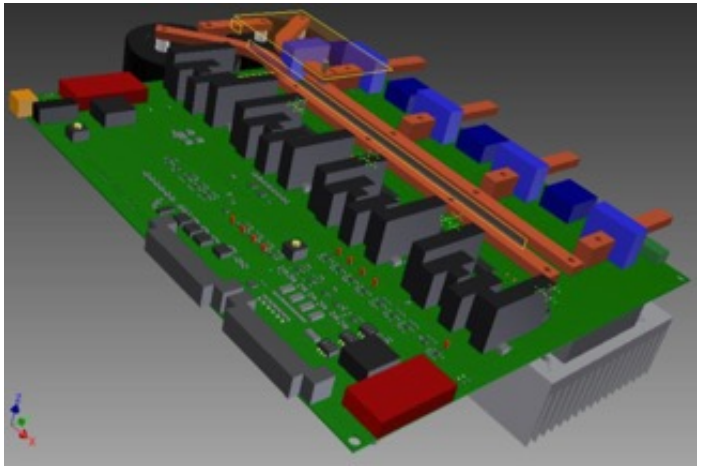


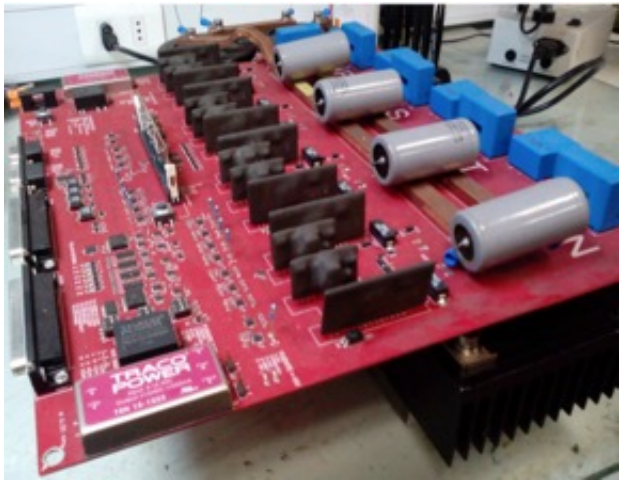
Methodology: Stage 4





Methodology: Stage 4

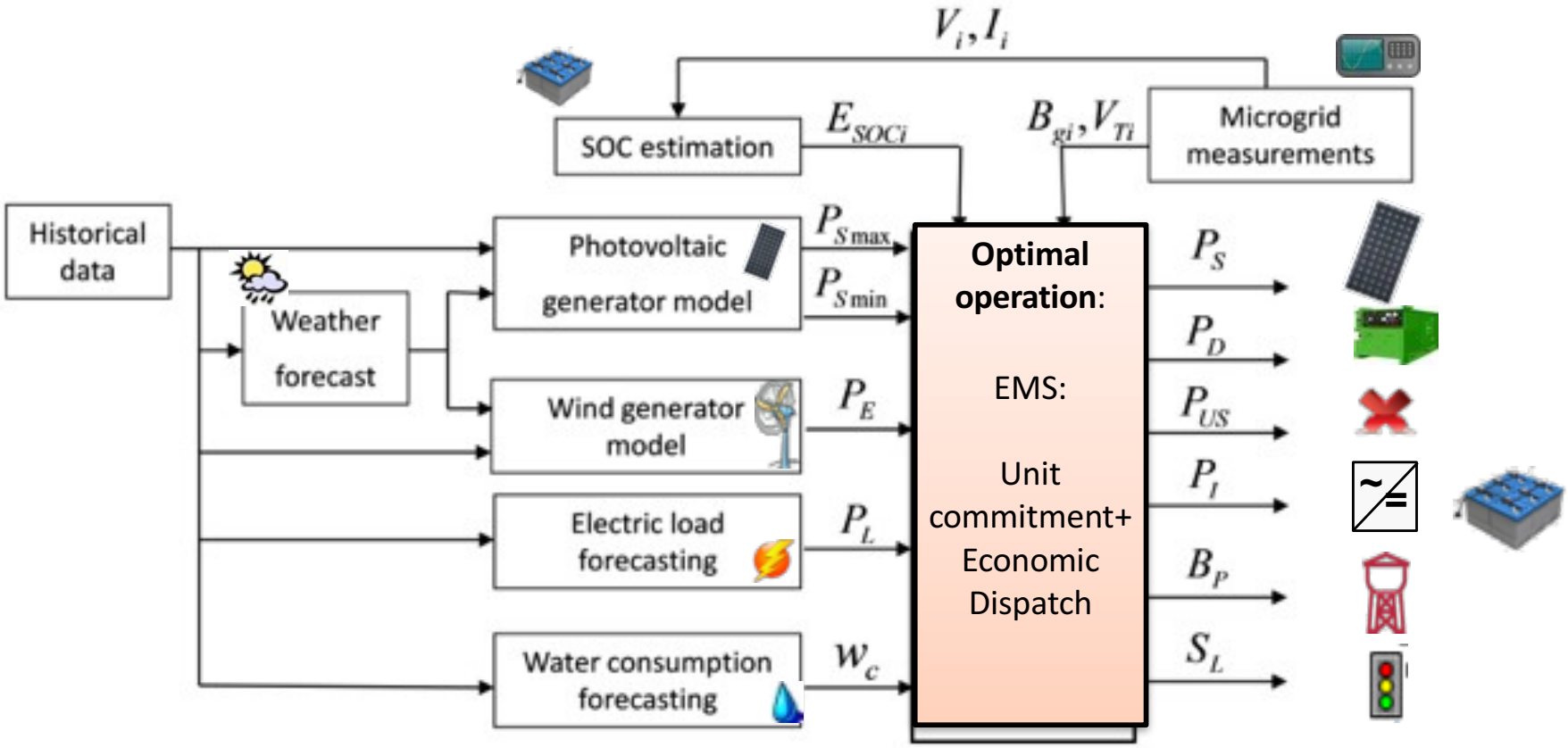




Agenda

- Co-construction methodology
- EMS
- Resilience capability
- Conclusions and challenges

Proposed EMS – Rolling Horizon



Inputs maximum and minimum available solar power (P_{Smax},P_{Smin}), wind power (P_E), load profile (P_L), water consumption (w_c), initial conditions for the battery charge (E_{SOC_i}), battery bank voltage (V_i) and current (I_i), water tank level (V_{Ti}) and diesel on/off state (B_{gi}).

Outputs 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).

Energy Management System

Objective function

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

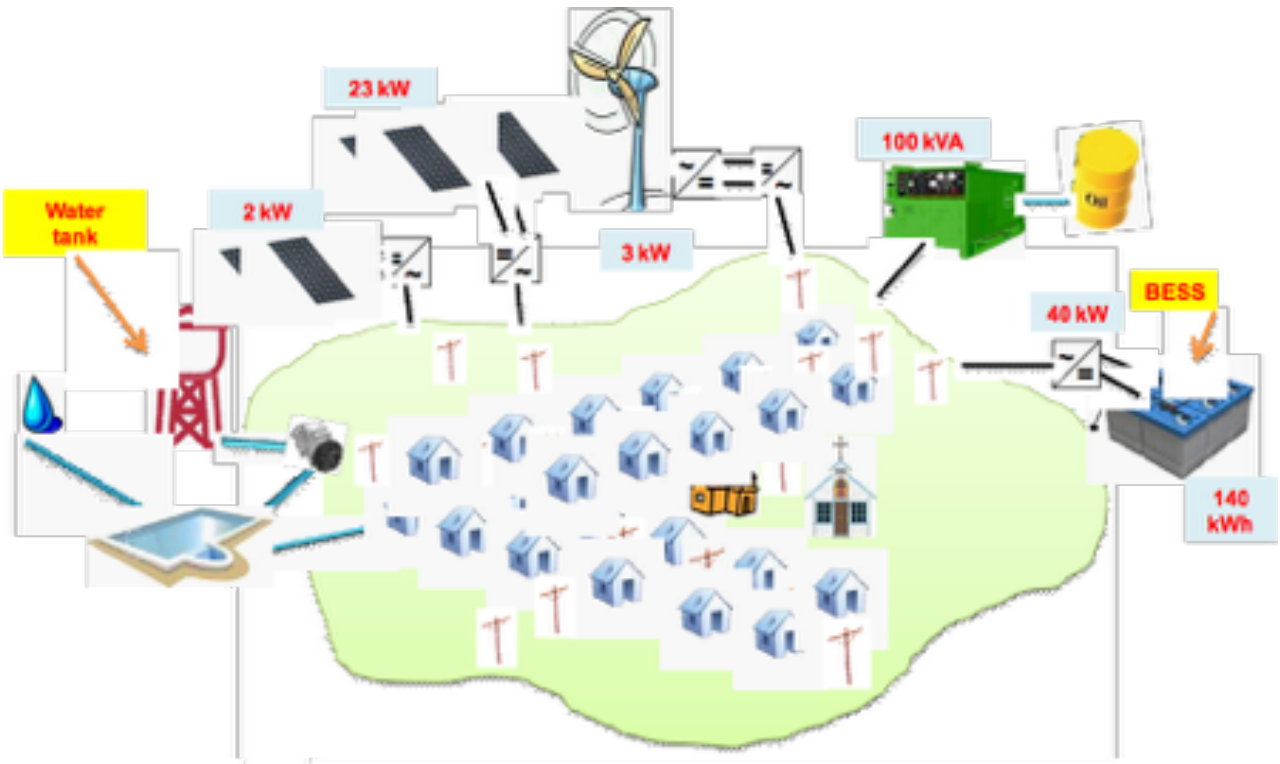
Diesel variable costs

Start-up diesel costs

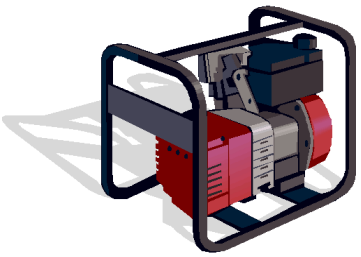
Penalization of the unsupplied energy

Penalization of the unserved water supply

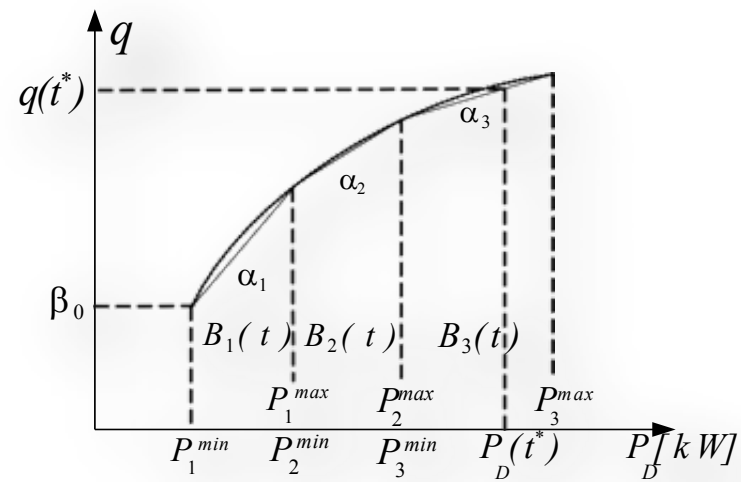
BESS lifetime penalization



Modeling of Conventional Units



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



$$B_g(t) = \sum_{v=1}^{n_v} B_v(t) \le 1 \qquad P_D(t) = \sum_{v=1}^{n_v} P_v(t)$$

$$P_v^{min} B_v(t) \le P_v(t) \le P_v^{max} B_v(t), \quad v = 1, \ldots, n_v$$

– *Start–up costs*

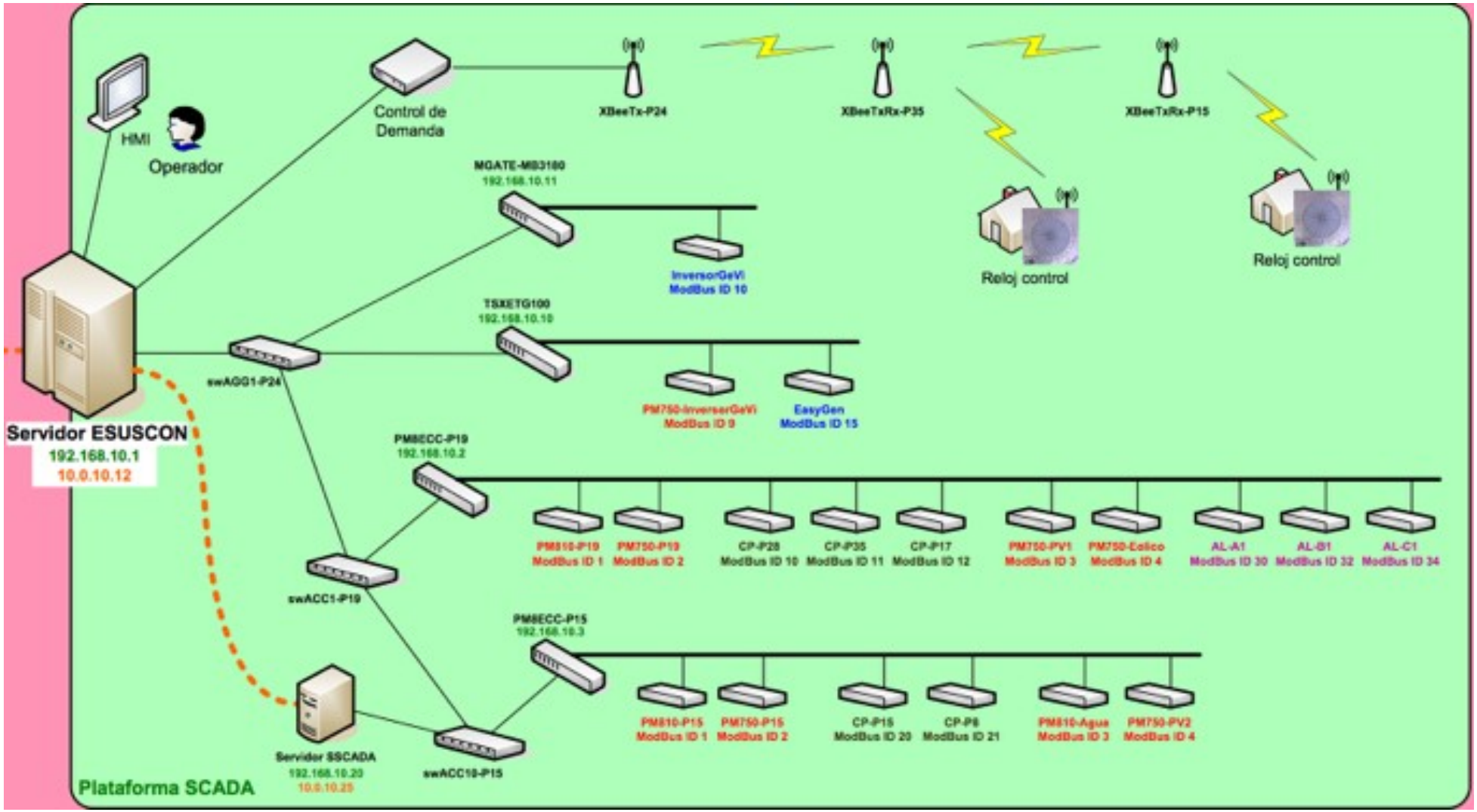
$$C_s(t) \ge C_D(B_g(t) - B_{g0}) \qquad t = 1$$

$$C_s(t) \ge C_D(B_g(t) - B_g(t-1)) \qquad t > 1$$

$$C_s(t) \ge 0$$

Control system

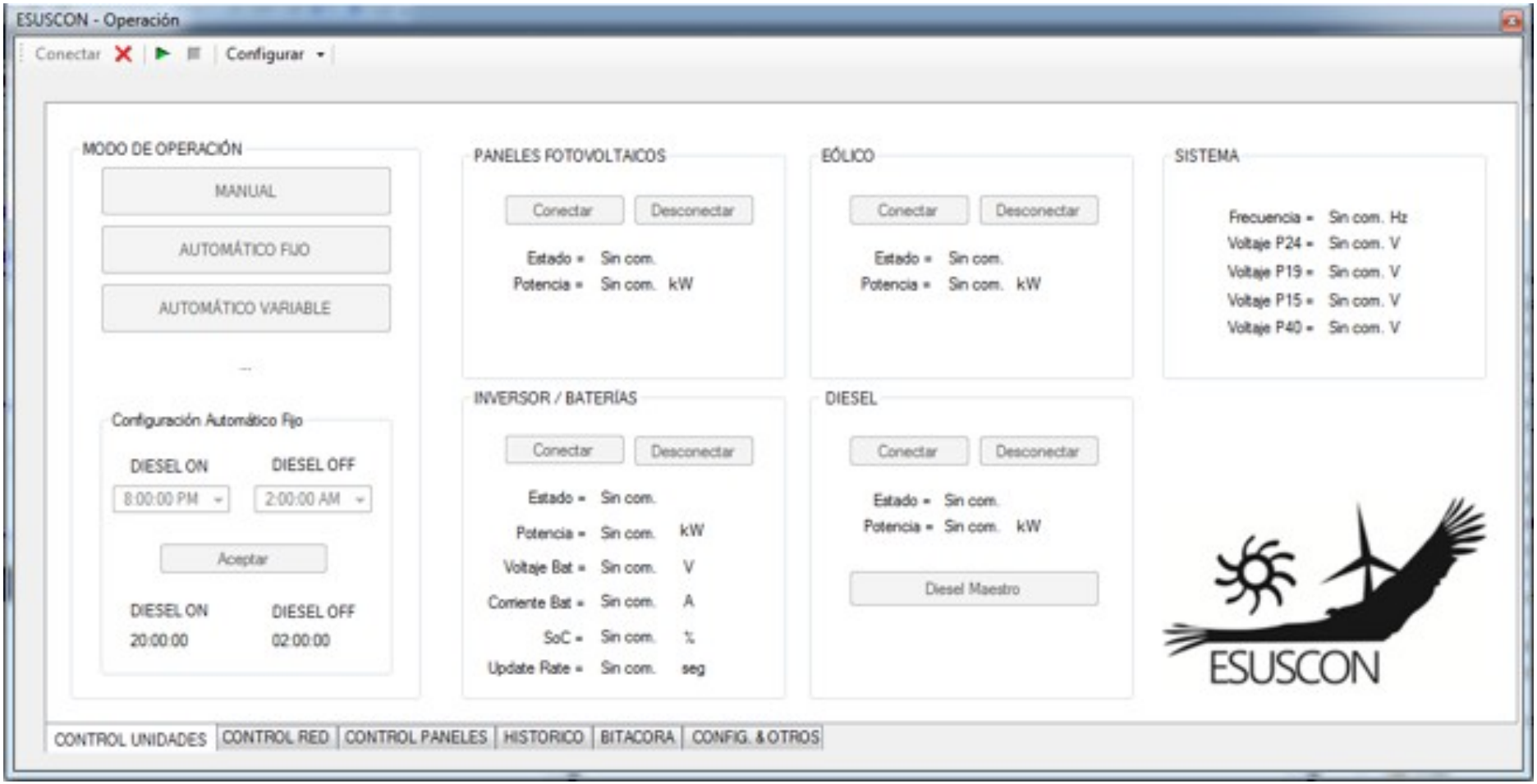
Measurement and control



Control software

.NET application-> “Operación Huatacondo”

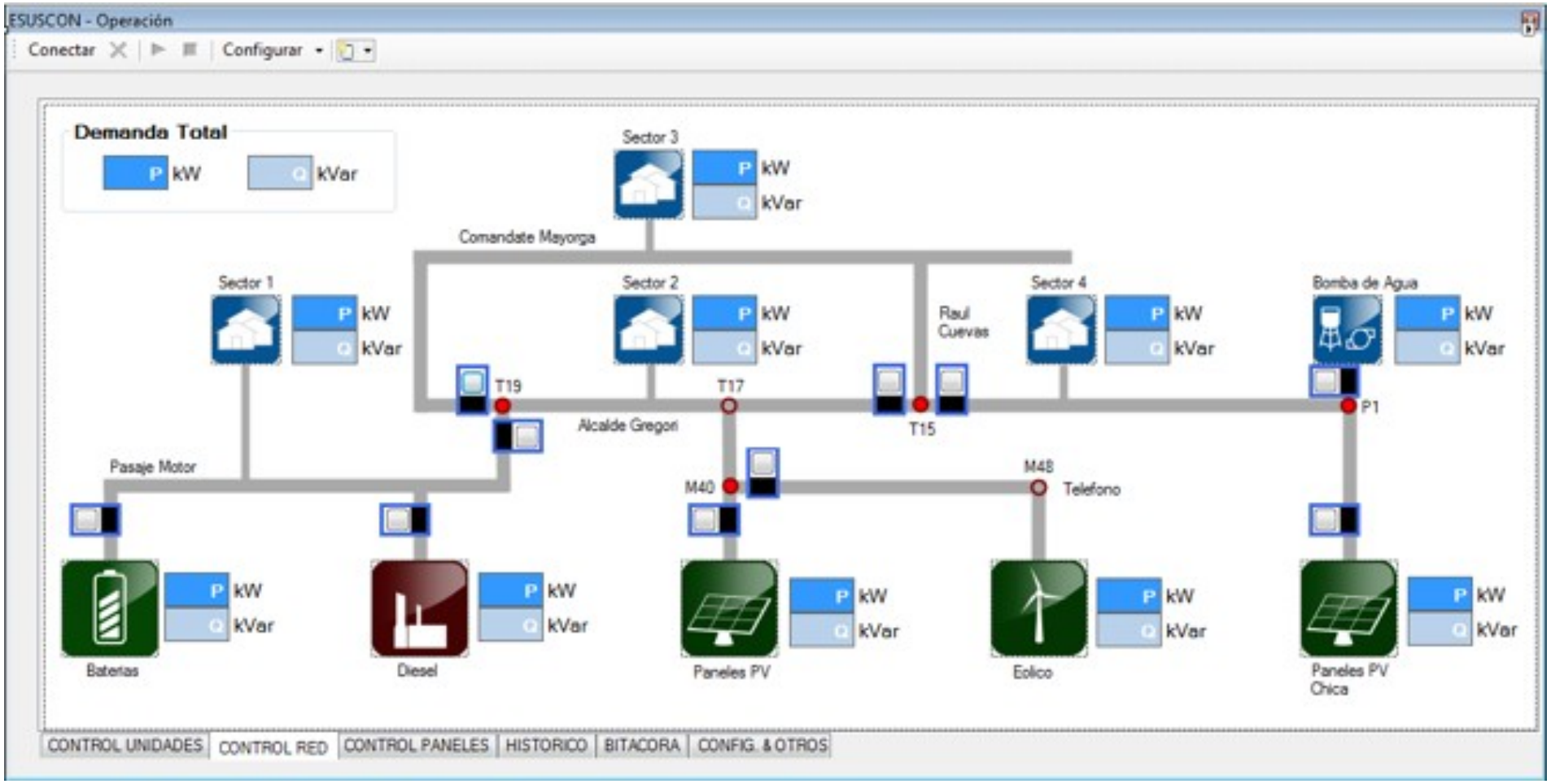
Control and monitoring per unit



Control software

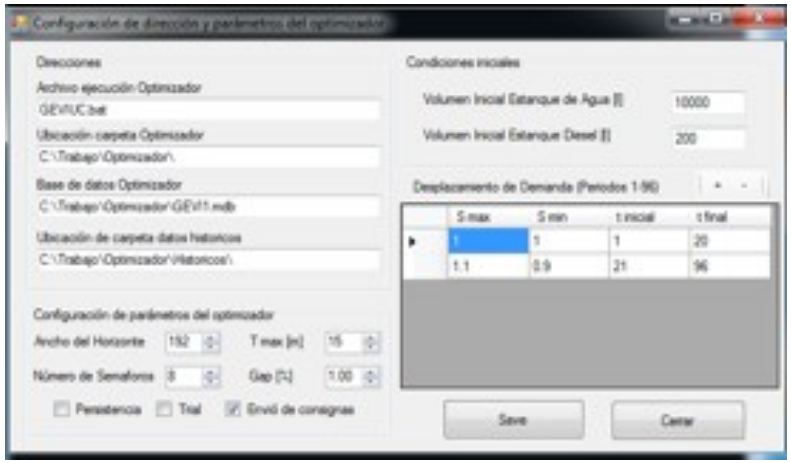
.NET application-> “Operación Huatacondo”

µGrid monitoring and control



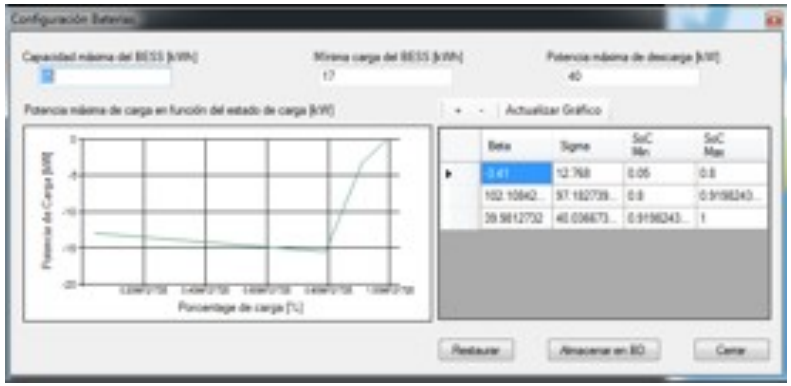
Control software

EMS Software



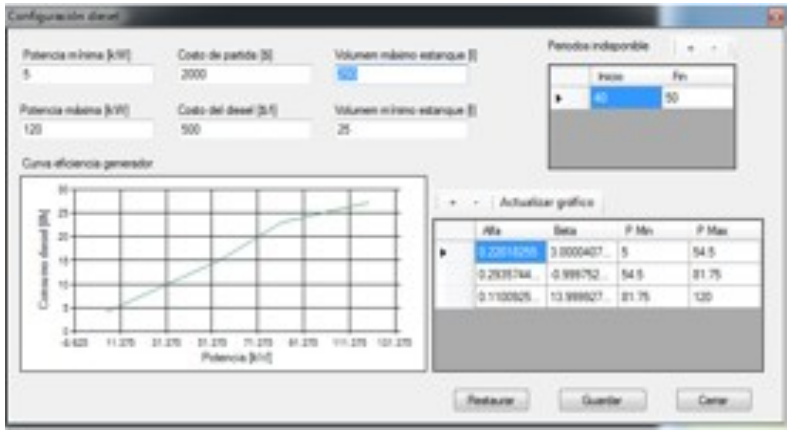
General configuration:

- DBs
- Optimization parameters
- DSM parameters



BESS configuration:

- Load curve
- Pmax, Cap (Ah), Efficiency

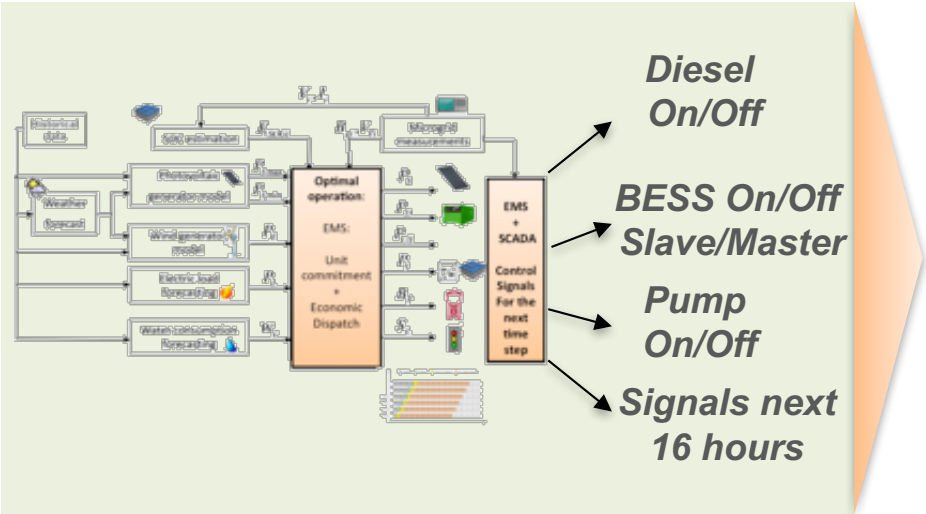


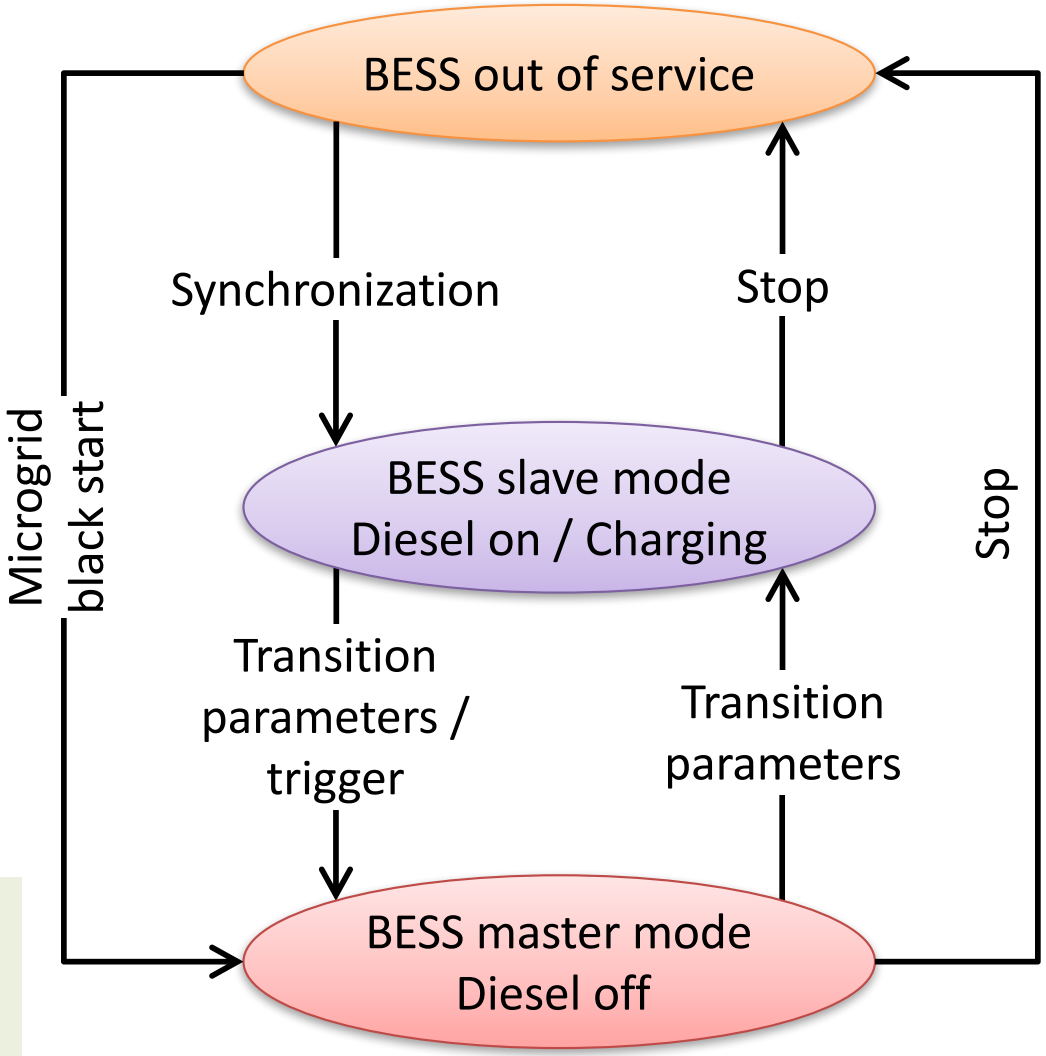
GenSet configuration:

- Consumption curve
- Pmax, Pmin
- Star-up costs, Diesel
- Operational constraints
- Diesel fuel storage

Control Issues

EMS set points → operation mode diagram for Huatacondo



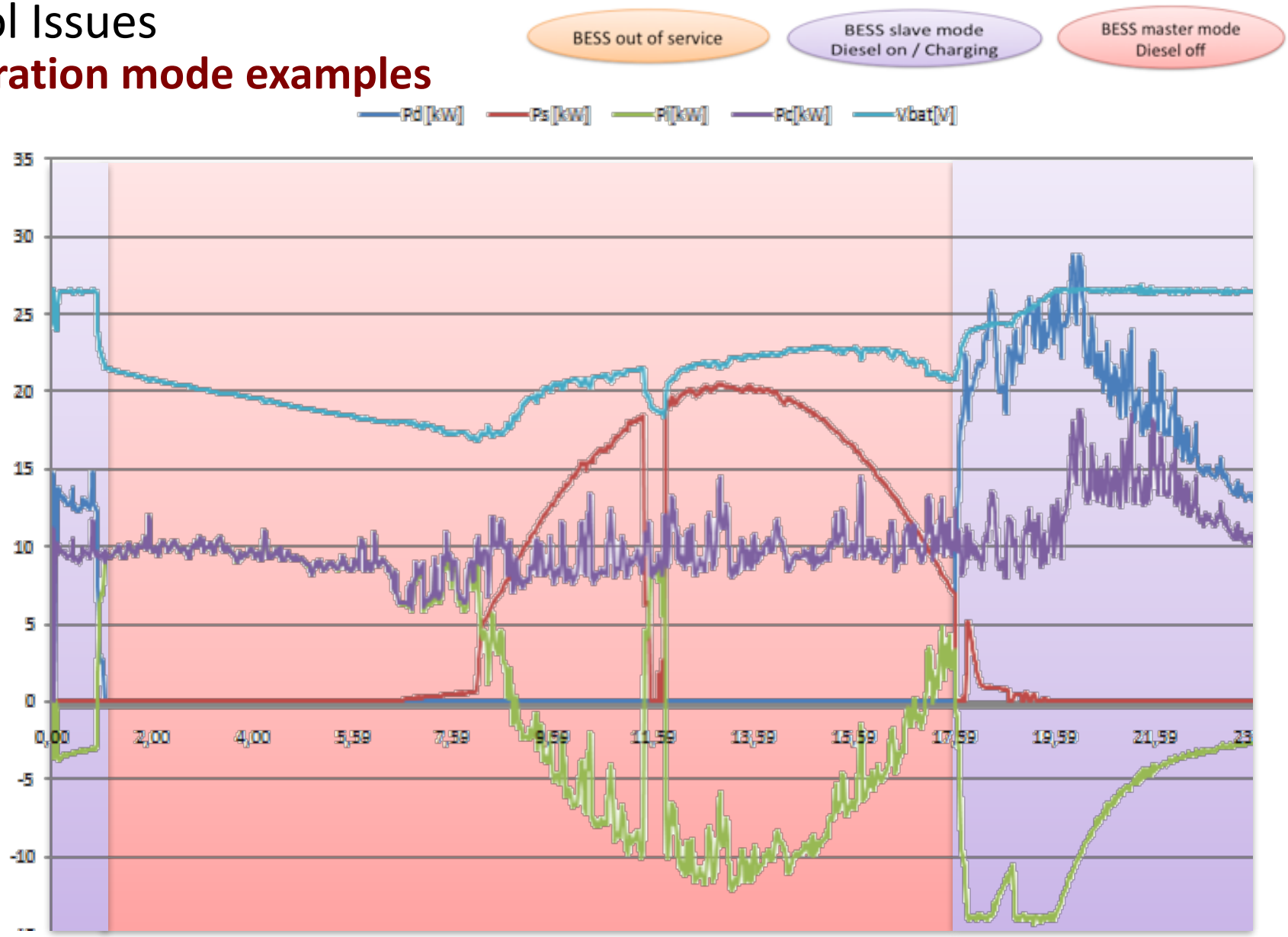


Additional issues:

- *Solar panel, wind always non dispatchable*
- *Pump independent of state*

Control Issues

Operation mode examples



Other EMS approaches

Continuous optimal control approaches to microgrid energy management

Benjamin Heymann[1] · J. Frédéric Bonnans[1] · Pierre Martinon[1] · Francisco J. Silva[2] · Fernando Lanas[3] · Guillermo Jiménez-Estévez[3]

$$(OCP)\begin{cases} \min_u \int_0^T \ell(u(t))\mathrm{d}t + g(x(T)) \\ \dot{x}(t) = F(u(t), t) \\ x(0) = x_0 \\ u(t) \in U_{x(t)} \\ x(t) \in \mathcal{C}. \end{cases}$$

$$S\dot{O}C(t) = \frac{1}{Q_B}(P_I(t)\rho_I - P_O(t)/\rho_O),$$

$$P_D + P_O + P_S + P_{slack} - P_L - P_I = 0.$$

$$\int_0^T K P_D(t)^{0.9}\mathrm{d}t,$$

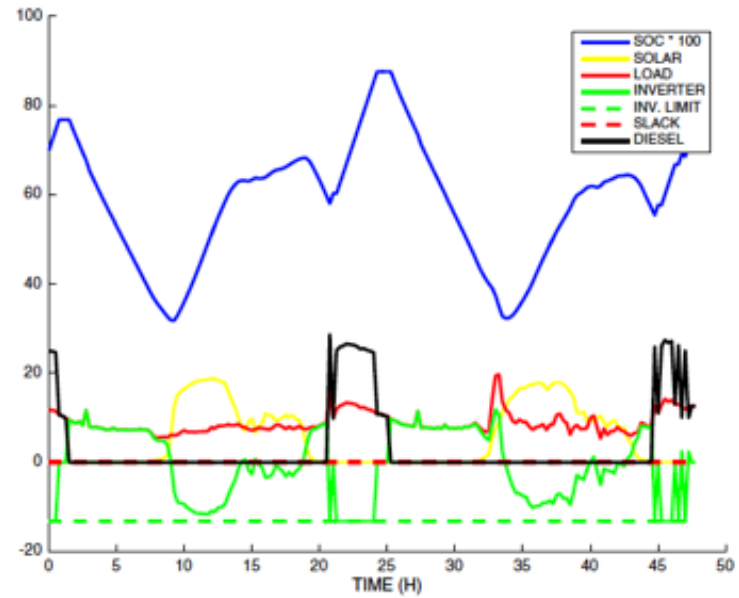


Fig. 5 Summer DPP simulation

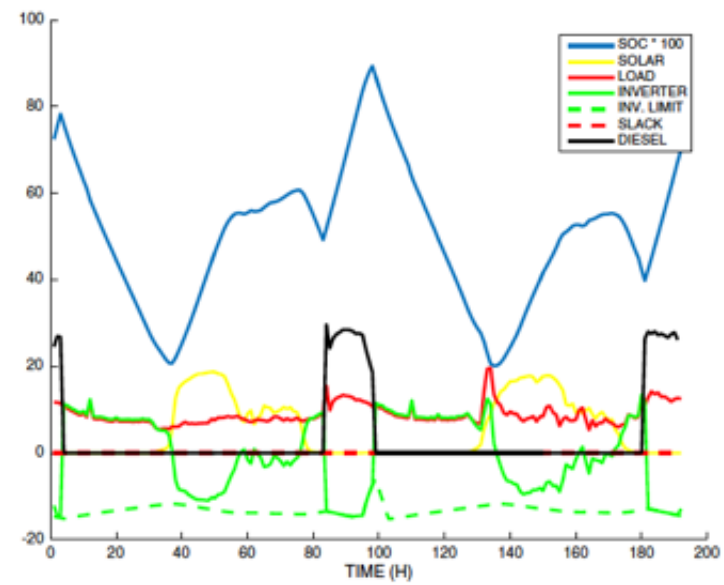


Fig. 9 Summer MILP simulation

Other EMS approaches

Rule based EMS

Microgrid operation with solar power spill (real perfomance)

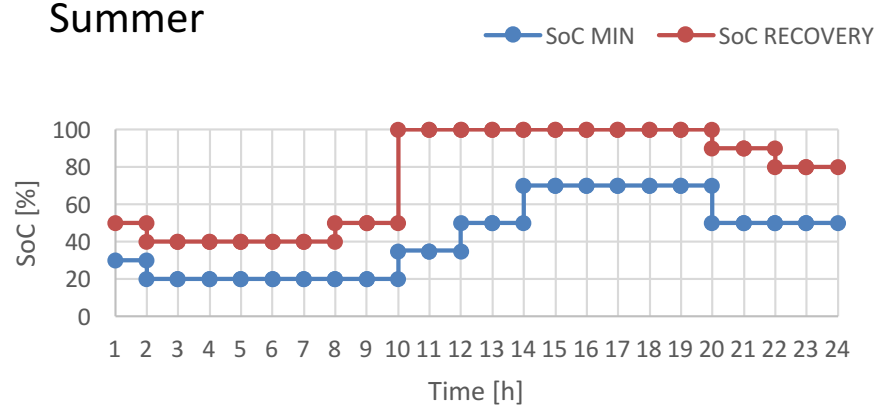
Other EMS approaches

Rule based EMS

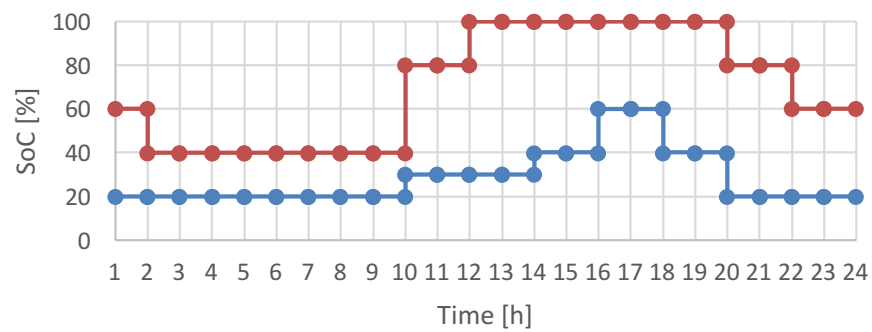
	Real performance	HOMER simulation
PV production [kWh]	316.997	447.764
Wind production [kWh]	29.538	50.905
Diesel based production [kWh]	360.875	157.366
Renewable fraction of consumption[%]	48,9	71,6
Diesel consumption [lt]	99.656	40.872
Non Served Energy [%]	-	0

New Rules → Homer

Summer



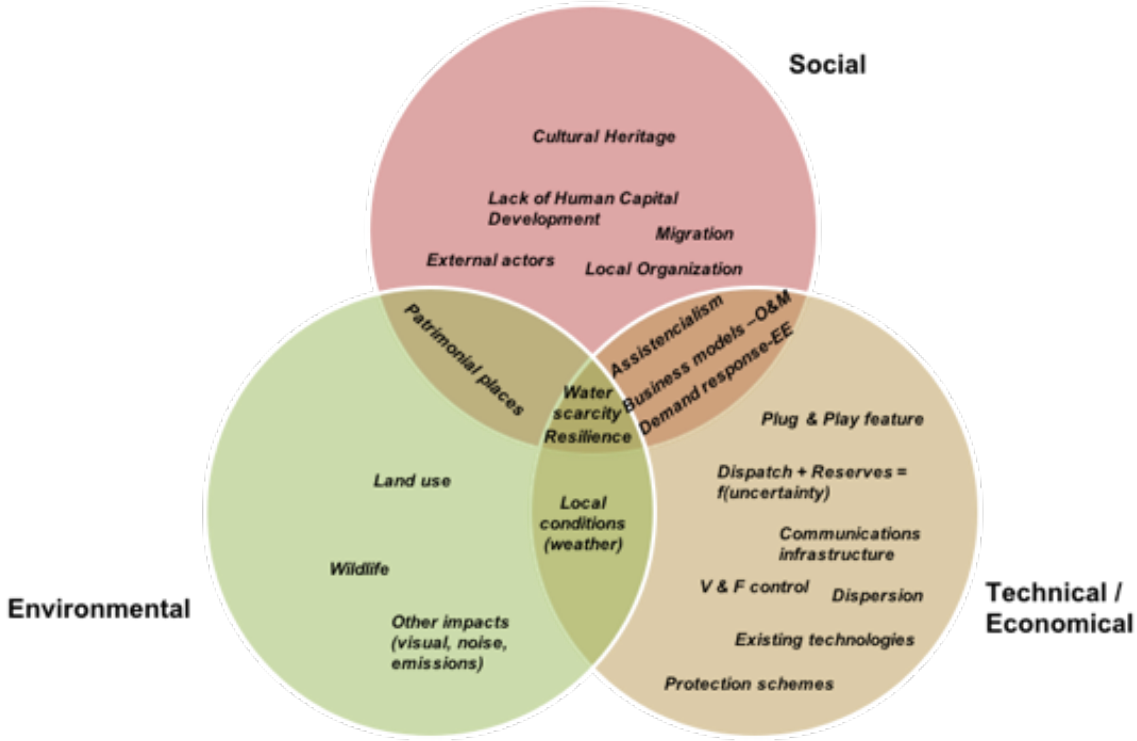
Autumn



Agenda

- Co-construction methodology
- EMS
- Resilience capability
- Conclusions and challenges

Microgrids – Resilience capability



Guillermo Jiménez-Estévez, Alejandro Navarro Espinosa, Rodrigo Palma-Behnke, Luigi Lanuzza and Nicolás Velázquez. Achieving Resilience at the Distribution Level. Learning from Isolated Community Microgrids. IEEE Power and Energy Magazine, May/June 2017

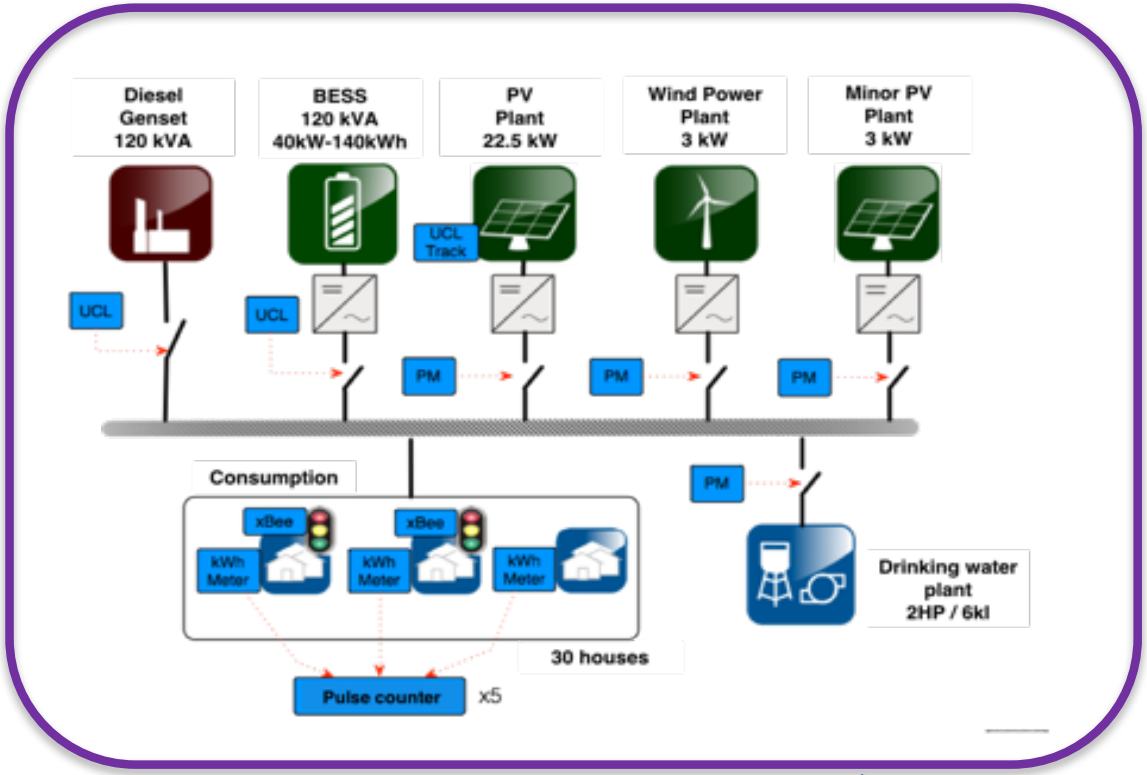
Resilient microgrid:

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



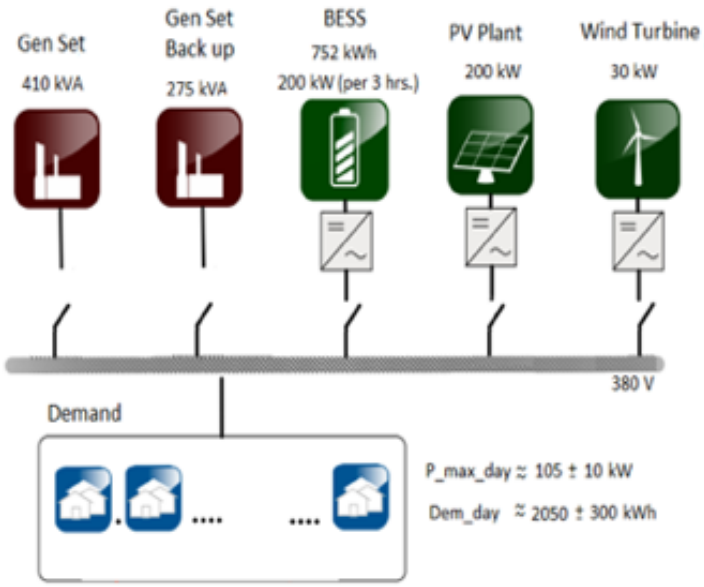
2012 Venida:

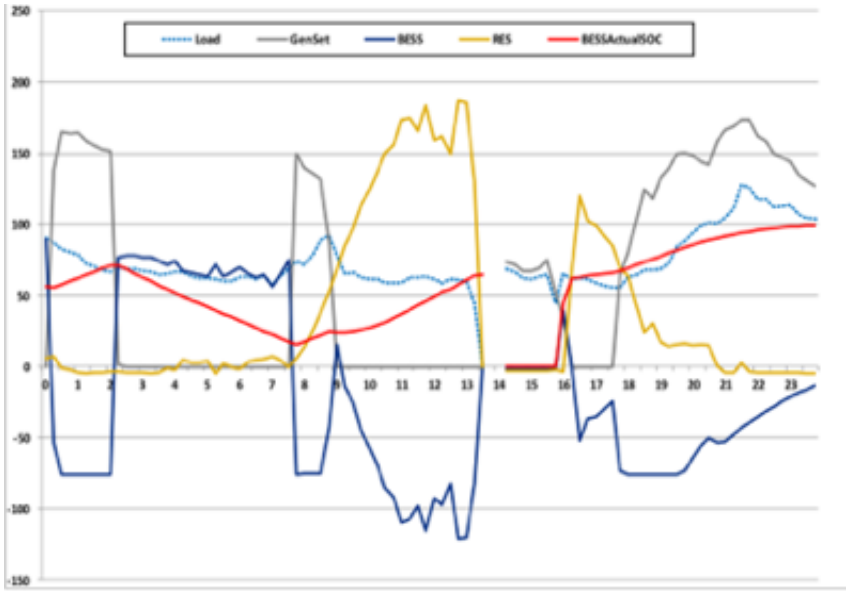
2014 IQQ Earthquake:

2014 Storm

Other experiences

Resilience capability

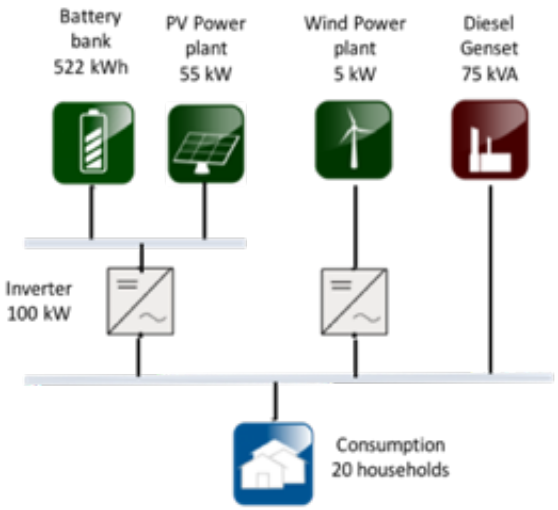


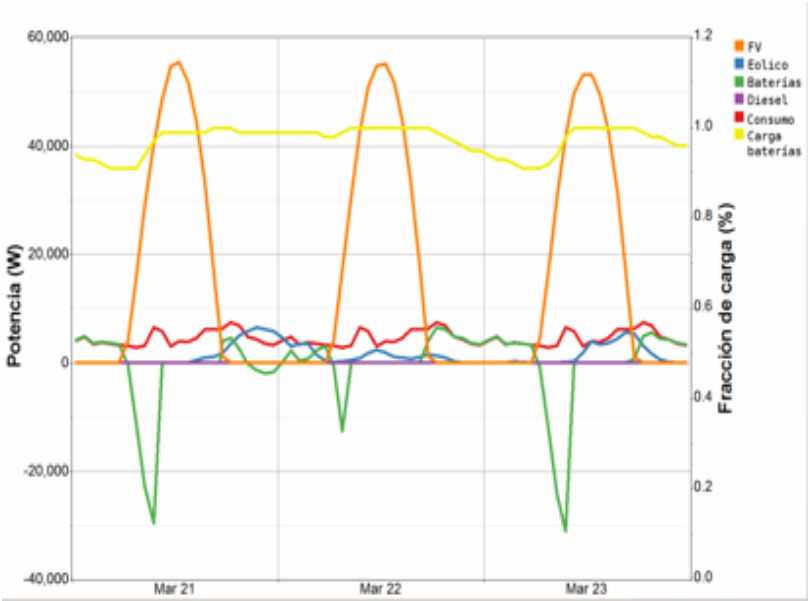


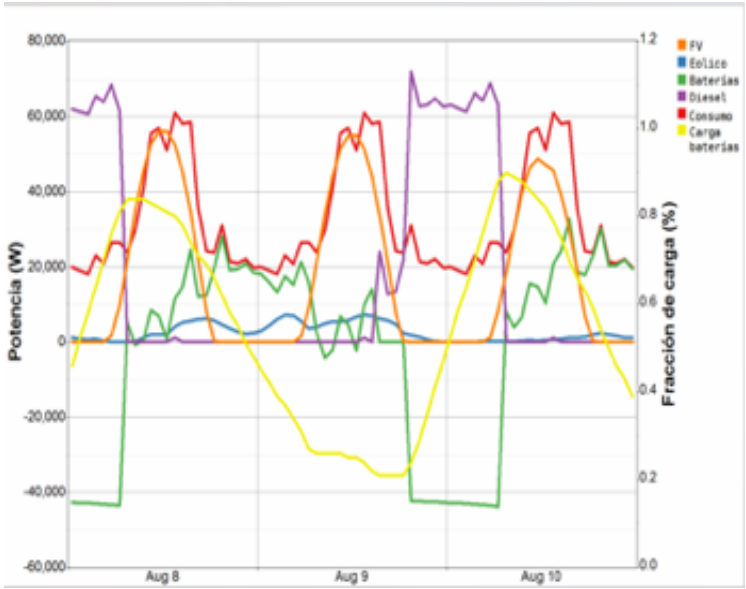
Ollagüe microgrid: microgrid diagram (left) and black start capability (right)..

Other experiences

Resilience capability





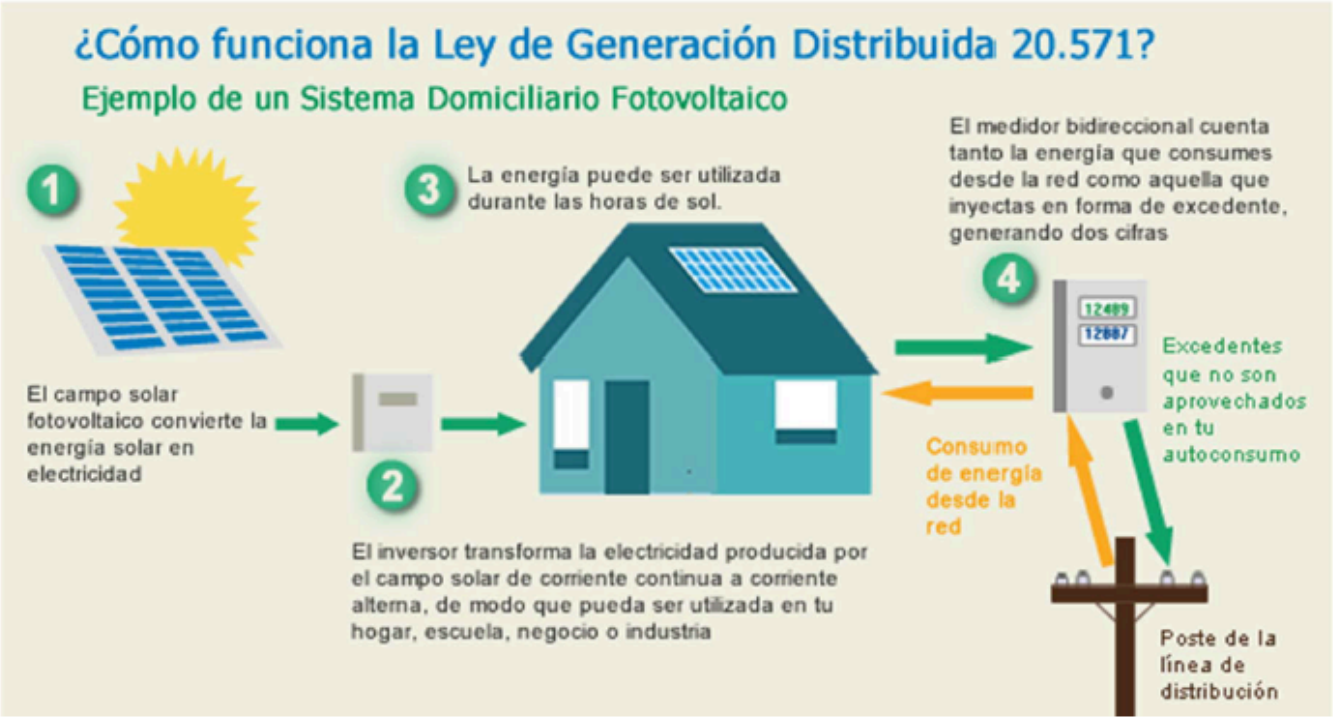


Puertecitos microgrid operation: low demand scenario (left) and high demand scenario (right)

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

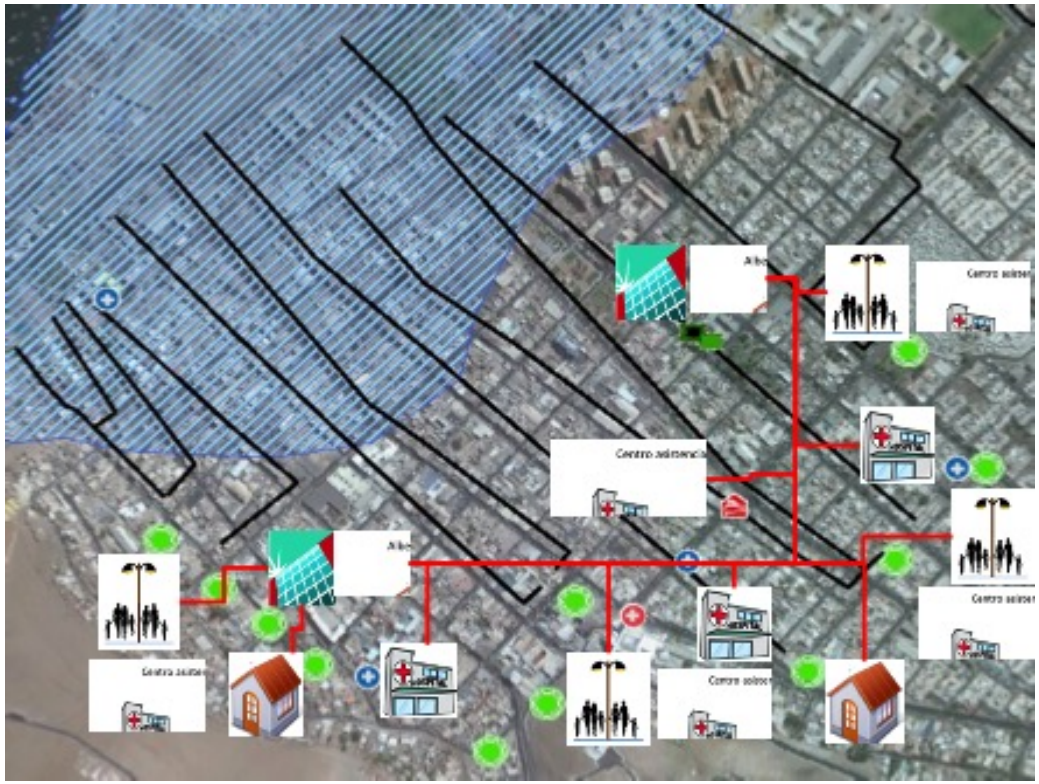
55.000 smart meters in Santiago

500 aggregators

BIG DATA !!
Multiple users → multiple interests

Grid Connected

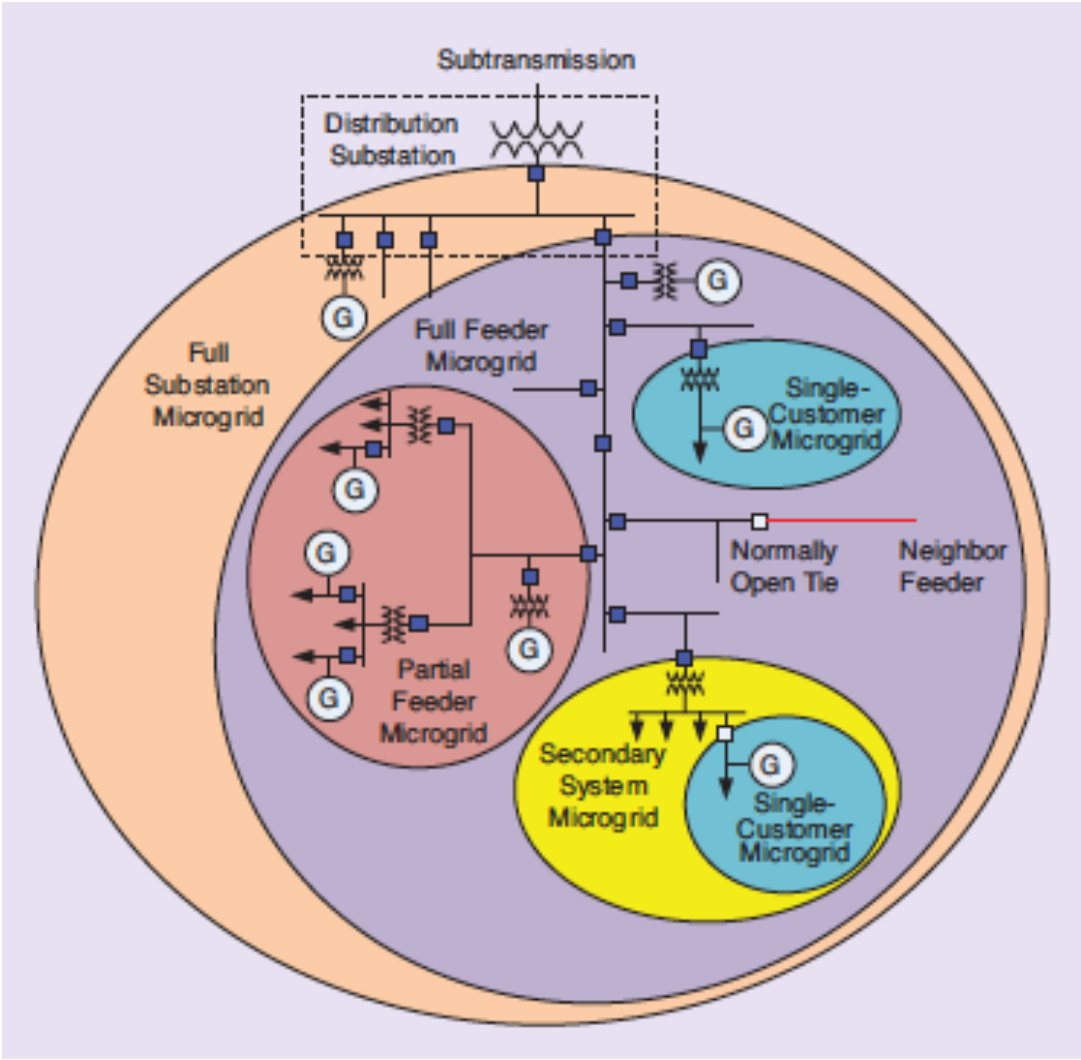
Pilot project – Arica (Emergency- Resilience)



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

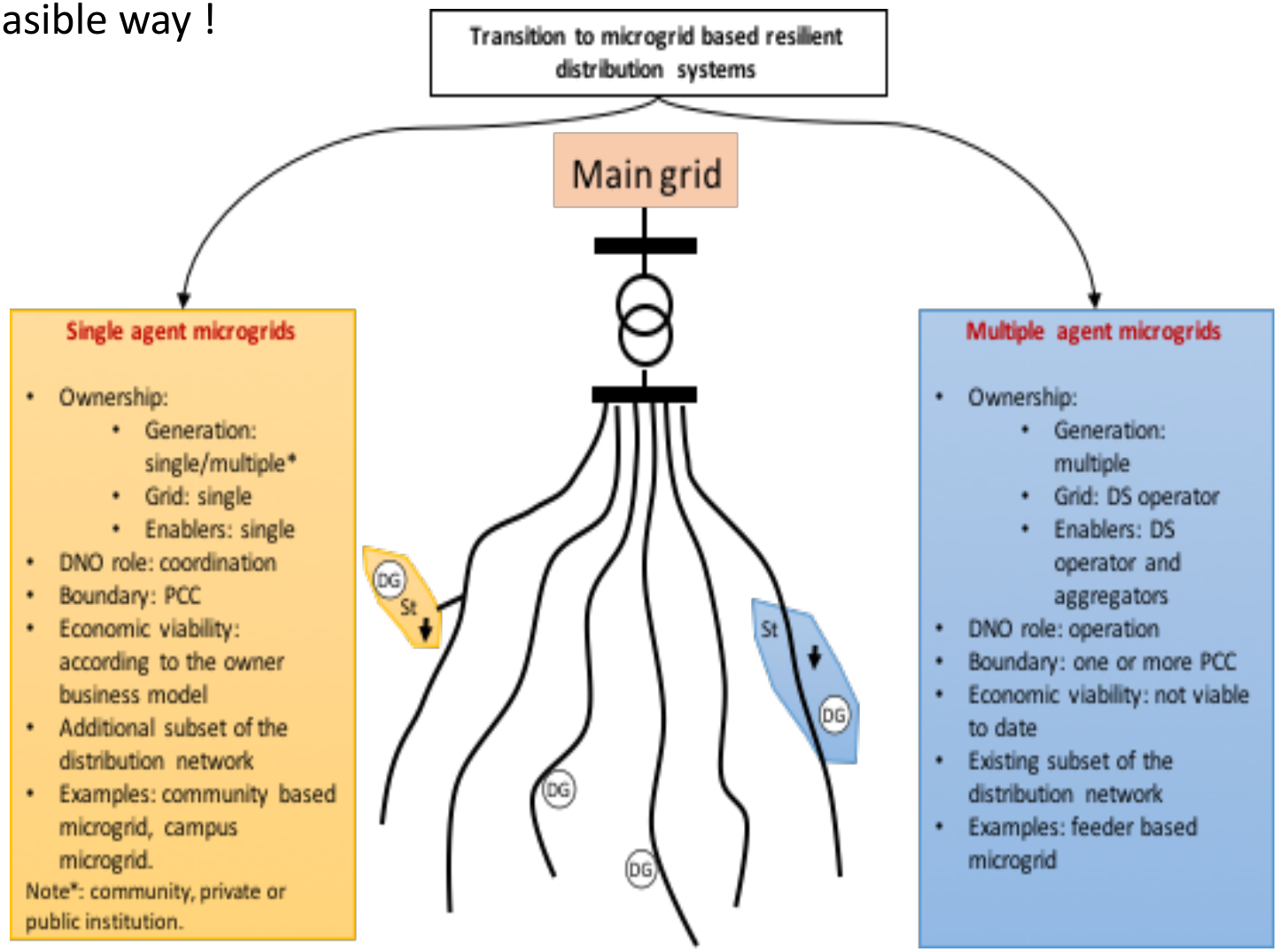
Operation of multiple microgrids



Julio Romero-Agüero, Amin Khodaei and Ralph Masiello. The Utility and Grid of the future. Challenges, needs and trends. IEEE Power and Energy Magazine, Sep/Oct 2016.

Grid Connected

One feasible way !



Guillermo Jiménez-Estévez, Alejandro Navarro Espinosa, Rodrigo Palma-Behnke, Luigi Lanuzza and Nicolás Velázquez. Achieving Resilience at the Distribution Level. Learning from Isolated Community Microgrids. IEEE Power and Energy Magazine, May/June 2017

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

Contacto
gjimenez@ing.uchile.cl

Resiliencia, flexibilidad y sostenibilidad