Resilience and Protection Schemes in Isolated Microgrids

Felipe Valencia Arroyave, Oscar Núñez Mata, Guillermo Jiménez Estévez, Rodrigo Palma Behnke

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Faculty of Physical Sciences and Mathematics
Universidad de Chile

Santiago

Outline

1. The Resilience Concept
2. Resilience and Protection Schemes
3. Case Study: The Huatacondo Microgrid
4. Concluding Remarks

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1. **The Resilience Concept**
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Definition of Resilience

The Stockholm Resilience Centre defined in 2012 resilience as the capacity of a system to continually change and adapt yet remain within critical thresholds.

Some Other Approaches

Several other definitions:

- The ability to bounce back to a single equilibrium.
- A measure of robustness or buffering capacity before a disturbance forces a system from one stable equilibrium to another.
- The ability to adapt in reaction to a disturbance.
- The underlying capacity of a system to maintain desired services in the face of a fluctuating environment.
- The capability to anticipate risk, limit impact, and bounce back rapidly through survival, adaptability, evolution, and growth in the face of turbulent change

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Microgrid Resilience

The capacity of a microgrid to continuously develop within human, technical, economical, and environmental boundaries.

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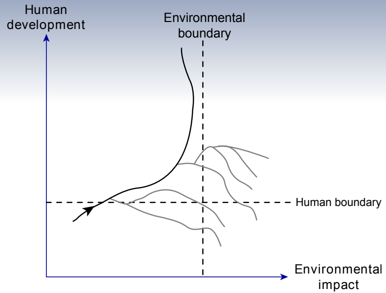

Expected scenario and events that generate deviations from it.

P. Becker, Conceptual frames for risk, resilience and sustainable development, in: P. Becker (Ed.), Sustainability Science, Elsevier, 2014, pp. 123-148.

Resilience Management Framework

This resilience definition requires:

- Identifying the critical functionality of the microgrid.
- Analysing the vulnerability of the components related with the critical functionality.
- Quantifying the loss of functionality of the microgrid as a consequence of an event

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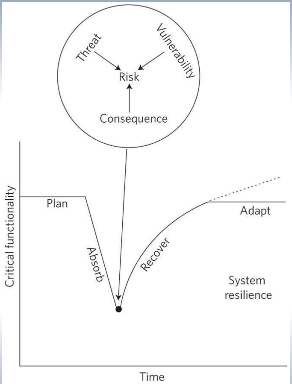

Resilience management framework.

I. Linkov, T. Bridges, F. Creutzig, J. Decker, C. Fox-Lent, W. Kroger, J. H. Lambert, A. Levermann, B. Montreuil, J. Nathwani, et al., Changing the resilience paradigm, Nature Climate Change 4 (6) (2014) 407–409.

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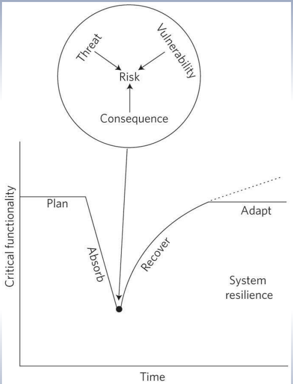
Absorb and Recovery Issues



- Absorb and recovery depend (among others) of the design of the protection schemes.
- The design of protection schemes for isolated grids is a challenging task.

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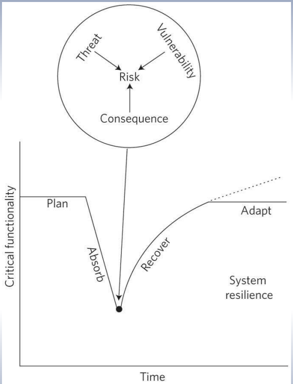

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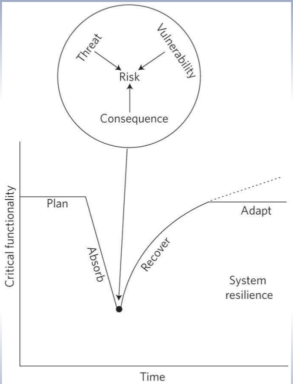

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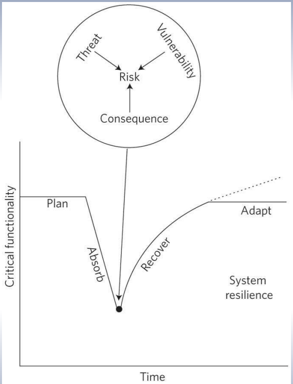

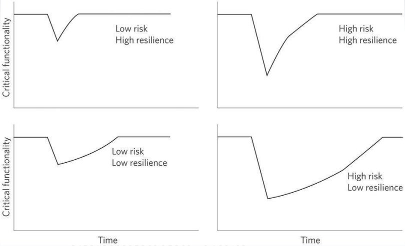

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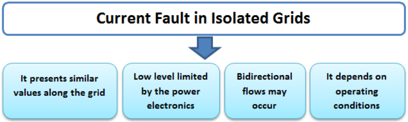
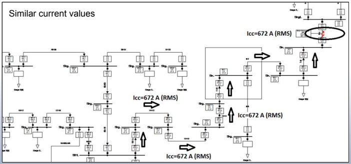


Protection Scheme Issues

Current Fault in Isolated Grids

- It presents similar values along the grid
- Low level limited by the power electronics
- Bidirectional flows may occur
- It depends on operating conditions



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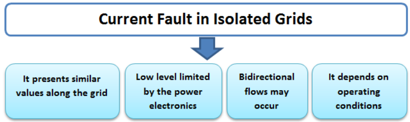

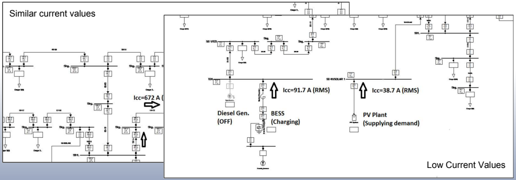

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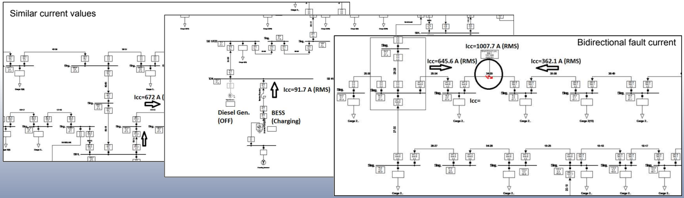

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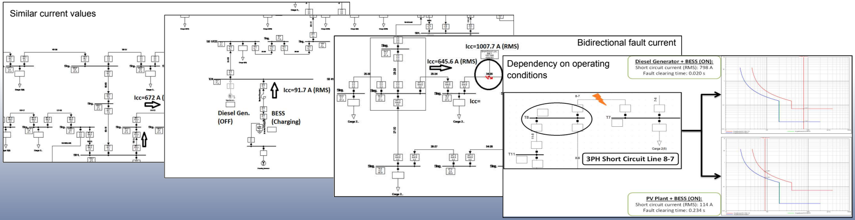

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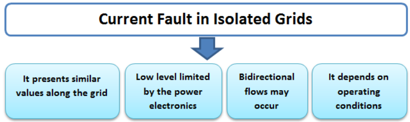
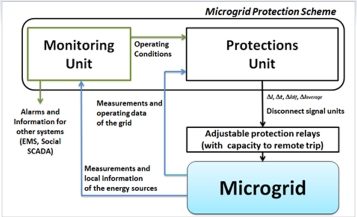


Aforementioned issues threaten the security of a microgrid and increase its vulnerability since, in case of failure, the selectivity, sensitivity, and time-response of conventional protection schemes is compromised. Thereby, the resilience of a microgrid with respect to system failures decreases.

Model-Based Adaptive Protection Scheme



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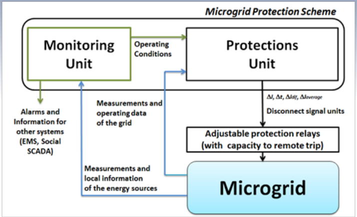
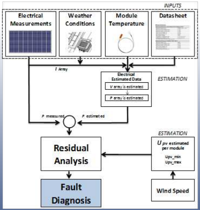
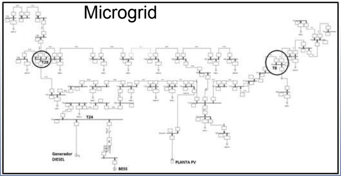


Monitoring unit





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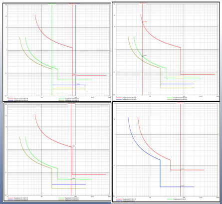

Some Considerations

The use of model-based adaptive protection schemes allowed us to:

1. Improve the coordination of the protection devises.
2. Capture peculiarities of isolated microgrids related with external factors.
3. Account for the state-of-health of energy sources in a microgrid.
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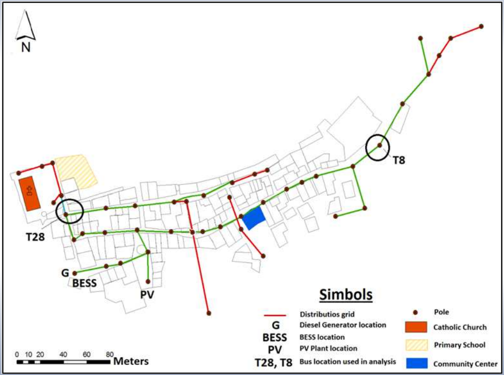
Huatacondo Microgrid



Resilience Assessment

- To assess the resilience of the Huatacondo microgrid historical information was used, specifically from 2012 and 2013.
- Based on this information the following indicators were defined:
  1. Frequency deviation.
  2. Voltage deviation.
  3. Plant factor of the PV plant.
  4. Percentage of the demand supplied with the PV plant.
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- The resilience management framework was formulated considering the following stages:
  1. Avoid (equivalent to Plan)
  2. Withstand (equivalent to Absorb)
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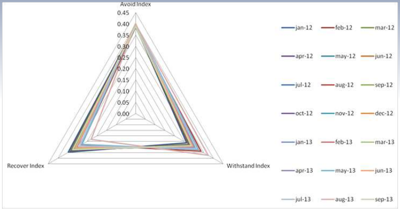

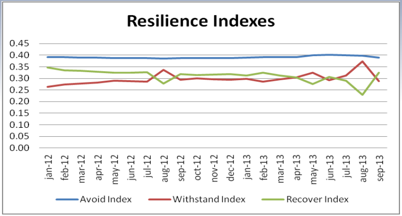

- The indexes show to which extend the resiliency of the Huataondo microgrid has been improved since 2011.
- The indexes also defines to which extend the critical functionality of the microgrid has been satisfied.
- Additional information has to be added in the study to accurately evaluate how resilient is the microgrid.

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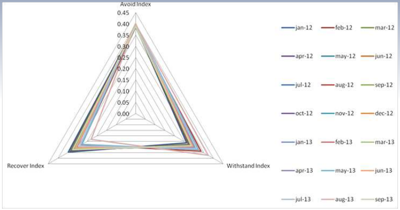

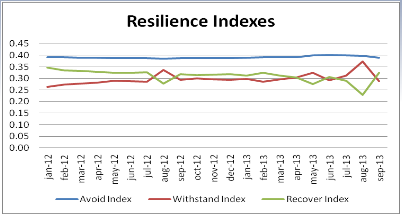

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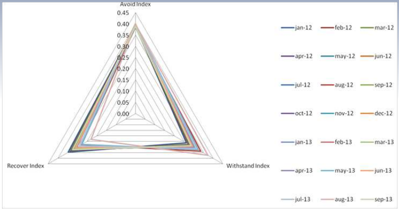

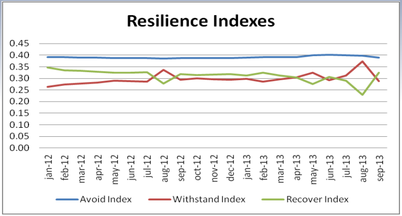

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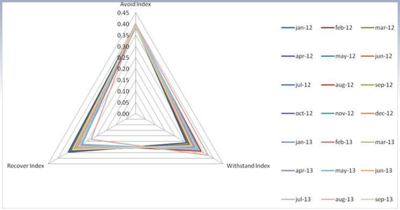

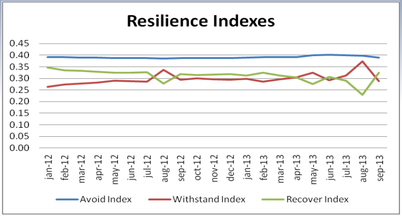

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Performance Assessment of the Monitoring Unit

Cases used in the experimental assessment of a PV array:

i) Normal operation.

ii) Partial shading condition.

iii) A module bypassed with a low resistance.

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Case	Measurement	U_{PV} Estimated [W/°C-m²]		U_{PV} Calculated [W/°C-m²]	Differences (%)		Comment about energy balance	Diagnosis
		Minimum	Maximum		Minimum	Maximun		
I)	I = 2.4 A P = 302.0 W T_m = 30.4 °C	27.9	31.2	27.8	0.4	10.9	Estimated and calculated values are consistent	Normal operation
II)	I = 0.34 A P = 53.9 W T_m = 28.4 °C			35.7	14.4	27,9	Estimated value is somewhat greater than calculated which corresponds to material with greater rate of exchange coefficient	Abnormal operation - not damaged
III)	I = 1.4 A P = 188.0 W T_m = 26.6 °C			39.9	27.9	43.0	Estimated value is greater than calculated which corresponds to material with greater rate of exchange coefficient	Abnormal operation - damaged

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As expected, the proposed monitoring unit was able to identify normal, abnormal, and failure operating conditions of the assessed PV array.

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Cases considered in the short-circuit analysis of the Huatacondo microgrid:

i) Diesel generator + BESS.

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Scenario 1: Diesel Generator + BESS

Bus	Bus Type	Event	Short Circuit Current (RMS)	Line Current Contribution (RMS)	Circuit Breaker Settings		
					ID #	Function 50	
						I_{inst} (A)	Time delay (ms)
T28	Loop	Three phase short circuit line L28-29	1021.9 A	L28-34: 204.2A	CBL28-34:	300	50
				L27-28: 817.7A	CBL27-28:	800	80
					CBL28-29:	200	30
T8	Radial	Three phase short circuit line L8-7	797.2A	L11-8: 797.2A	CBL11-8:	400	40
					CBL8-7:	200	20

Scenario 2: PV Plant + BESS

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T28	Loop	Three phase short circuit line L28-29	114.9A	L28-34: 29.4A	CBL28-34:	200	50
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Due to the differences of the currents during the fault, the settings of the relays should be modified to keep the security and integrity of the microgrid.

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1 The Resilience Concept

2 Resilience and Protection Schemes

3 Case Study: The Huatacondo Microgrid

4 Concluding Remarks

Summary

- A framework for resilience management was presented.
- Under this framework, the importance of an adequate design of the protection schemes in microgrids was discussed.
- A new framework for the design of protection schemes was introduced. This framework combines monitoring with adaptive protection schemes to overcome the challenges in the design of protection schemes arising in microgrid applications.
- The Huatacondo microgrid was used as test-bench to evaluate the new framework for protection schemes, as well as for the assessment of the resilience in a microgrid.

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Resilience and Protection Schemes in Isolated Microgrids

Felipe Valencia Arroyave, Oscar Núñez Mata, Guillermo Jiménez Estévez, Rodrigo Palma Behnke

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Faculty of Physical Sciences and Mathematics
Universidad de Chile

Santiago