Resilience and Protection Schemes in Isolated Microgrids

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Outline

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

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2. Resilience and Protection Schemes
3. Case Study: The Huatacondo Microgrid
4. Concluding Remarks
The Stockholm Resilience Centre defined in 2012 resilience as the capacity of a system to continually change and adapt yet remain within critical thresholds.
The Resilience Concept

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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Expected scenario and events that generate deviations from it.

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.

Resilience and Protection Schemes

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Absorb and recovery depend (among others) on the design of the protection schemes.

The design of protection schemes for isolated grids is a challenging task.

Resilience management framework

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Resilience and Protection Schemes

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
Resilience and Protection Schemes

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Resilience and Protection Schemes

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Low Current Values
Resilience and Protection Schemes

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Bidirectional fault current
Resilience and Protection Schemes

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Similar current values

Bidirectional fault current

Dependency on operating conditions

FVA-2015 Aalgorg Microgrids Symposium
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.
Resilience and Protection Schemes

Model-Based Adaptive Protection Scheme

- Monitoring Unit
  - Operating Conditions
  - Alarms and information for other systems (EMS, Social SCADA)
- Protections Unit
  - Measurements and operating data of the grid
  - Disconnect signal units
- Microgrid
  - Adjustable protection relays (with capacity to remote trip)
Resilience and Protection Schemes

Model-Based Adaptive Protection Scheme

Monitoring unit

Microgrid

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

1. **Improve the coordination of the protection devices.**
2. Capture peculiarities of isolated microgrids related with external factors.
3. Account for the state-of-health of energy sources in a microgrid.
4. Enhance the resilience of a microgrid with respect to system failures.
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Case Study: The Huatacondo Microgrid

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Huatacondo Microgrid

![Map of Huatacondo Microgrid](image)

**Symbols**
- **G**: Diesel Generator location
- **BESS**: BESS location
- **PV**: PV Plant location
- **T28, T8**: Bus location used in analysis
- **Pole**: Pole
- **Catholic Church**: Orange
- **Primary School**: Yellow
- **Community Center**: Blue

FVA-2015 Aalborg Microgrids Symposium
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:

- Frequency deviation
- Voltage deviation
- Plant factor of the PV plant
- Percentage of the demand supplied with the PV plant
- Percentage of change of diesel consumption
- Percentage of change of the price per kW
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The resilience management framework was formulated considering the following stages:

1. Avoid (equivalent to Plan)
2. Withstand (equivalent to Absorb)
3. Recovery (equivalent to Recover + Adapt)

The contribution of each indicator to each of the aforementioned stages was evaluated.

The resilience of the microgrid was evaluated based on the scores obtained for each stage.
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Case Study: The Huatacondo Microgrid

Resilience Assessment

- The indexes show to which extent the resiliency of the Huatacondo microgrid has been improved since 2011.
- The indexes also define to which extent 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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Case Study: The Huatacondo Microgrid

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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Results:

<table>
<thead>
<tr>
<th>Case Measurement</th>
<th>Un-Estimated [W/C-m²]</th>
<th>Un-Calculated [W/C-m²]</th>
<th>Differences (%)</th>
<th>Comment about energy balance</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>i)</td>
<td>27.9</td>
<td>27.8</td>
<td>0.4</td>
<td>10.9</td>
<td>Normal operation</td>
</tr>
<tr>
<td>P = 39.2 W</td>
<td></td>
<td></td>
<td></td>
<td>Estimated and calculated values are consistent</td>
<td>Normal operation</td>
</tr>
<tr>
<td>T = 30.4 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Normal operation</td>
</tr>
<tr>
<td>ii)</td>
<td>35.7</td>
<td>31.2</td>
<td>14.4</td>
<td>27.9</td>
<td>Abnormal operation - not damaged</td>
</tr>
<tr>
<td>P = 63.9 W</td>
<td></td>
<td></td>
<td></td>
<td>Estimated value is somewhat greater than calculated which corresponds to material with greater rate of exchange coefficient</td>
<td>Abnormal operation - not damaged</td>
</tr>
<tr>
<td>T = 28.4 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Abnormal operation - not damaged</td>
</tr>
<tr>
<td>iii)</td>
<td>39.9</td>
<td>27.9</td>
<td>43.0</td>
<td>Estimated value is greater than calculated which corresponds to material with greater rate of exchange coefficient</td>
<td>Abnormal operation - damaged</td>
</tr>
<tr>
<td>P = 188.0 W</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Abnormal operation - damaged</td>
</tr>
<tr>
<td>T = 26.6 °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Abnormal operation - damaged</td>
</tr>
</tbody>
</table>
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.

Results:

As expected, the proposed monitoring unit was able to identify normal, abnormal, and failure operating conditions of the assessed PV array.
Cases considered in the short-circuit analysis of the Huatacondo microgrid:

i) Diesel generator + BESS.

ii) PV plant + BESS.
Case Study: The Huatacondo Microgrid

Assessment of the Protection Unit

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Results:

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.
Concluding Remarks

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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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