PLANNING THE INTEGRATION OF DER IN THE COLOMBIAN POWER GRID

System Planning Impacts of DER Working Group (SPIDERWG)
January 09 2019
Colombian Power System Overview
The Colombian power system

Demand: 68,000 GWha

Capacity: 17.3 GW
Peak Load: 10 GW
Variable generation: 1.5 GW

66% Hidro
28% Thermal
1.4 GW Hidro
80 MW PV
20 MW Wind

Source: UPME October 2018
DER – Current Situation

- 30 Regional Operators (OR)
- Diversity in size of the jurisdictions and technical and economic capacity of the ORs
- Planning, supervision, coordination and control of the ISO limited
- Visibility only for plants above 5 MW
- Small Run Of River plants about 77% of installed capacity
- Generation below 1 MW represents 2.5% of the installed capacity and 25% of the plants
- Incipient demand and low incentives for energy efficiency

<table>
<thead>
<tr>
<th>Plants</th>
<th>Capacity [MW]</th>
<th>Capacity [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small hydro</td>
<td>94</td>
<td>488</td>
</tr>
<tr>
<td>Thermal</td>
<td>5</td>
<td>34</td>
</tr>
<tr>
<td>Cogeneration</td>
<td>17</td>
<td>116</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>116</strong></td>
<td><strong>638</strong></td>
</tr>
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205 MW (42% del total) of small hydro in Antioquia
Cogeneration (biomass) concentrated in Valle
• Around 2 GW de proyectos oficialmente registrados con capacidad menor a 20 MW
• 52% de la capacidad total corresponde a proyectos solares - 45% proyectos hidroeléctricos pequeños
• 63% de los proyectos registrados tienen capacidad por debajo de 1 MW - Menos de 2% de la capacidad total
• 97% de los proyectos por debajo de 1 MW son solares
• Los sistemas de almacenamiento de energía pueden ser utilizados a corto plazo principalmente para el manejo de congestión
• Programas de respuesta a la demanda solo están comenzando a explorarse

Expected DER Development

- La concentración más alta de proyectos solares de menos de 1 MW se encuentra alrededor de Bogotá (22% del total)
- 75% de los proyectos solares están concentrados en el norte del país, donde 85% son proyectos mayores de 10 MW
- 55% de los proyectos hidroeléctricos pequeños se encuentran en Antioquia

<table>
<thead>
<tr>
<th>Tipo de Energía</th>
<th>Proyectos</th>
<th>Capacidad [MW]</th>
<th>Capacidad [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar PV</td>
<td>366</td>
<td>1137</td>
<td>51.9%</td>
</tr>
<tr>
<td>Pequeño hidroeléctrico</td>
<td>93</td>
<td>978</td>
<td>44.6%</td>
</tr>
<tr>
<td>Biomasa térmica</td>
<td>16</td>
<td>66</td>
<td>3.0%</td>
</tr>
<tr>
<td>Viento</td>
<td>3</td>
<td>10</td>
<td>0.5%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>478</strong></td>
<td><strong>2190</strong></td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>
Planning studies to understand the potential impact
Objectives:

• First approach to identify and quantify the system impacts

• Start discussion with stakeholders and regulatory commission on basic technical requirements -from the perspective of the System Operator -

Electrical analysis: Dynamic simulations and steady state calculations

- Focus on specific areas of the system according to signals of possible development
- Incremental participation growth scenarios to understand the impact
### Scenarios for developing the studies

<table>
<thead>
<tr>
<th>Scenario 1: Massive development of Retail DER (&lt;1 MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Gradual increase of installed capacity until finding systemic impacts – Initially no ride trough capability assumed</td>
</tr>
<tr>
<td>• Aggregate modeling of DER in parallel with loads – Development of a composite Load Model is a project for 2019 -</td>
</tr>
<tr>
<td>• Focus on eastern area (Bogotá)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario 2: Massive development of Utility Scale DER (&gt;5 MW)</th>
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</thead>
<tbody>
<tr>
<td>• Location and capacity according to existing connection requests</td>
</tr>
<tr>
<td>• The plants are modeled individually according to the requested connection point</td>
</tr>
<tr>
<td>• Focus on northern area (Caribbean)</td>
</tr>
<tr>
<td>• Voltage &lt;33 kV: Trafo plus equivalent impedance</td>
</tr>
<tr>
<td>• Voltage &gt; 33 kV: Trafo</td>
</tr>
</tbody>
</table>
Identified impacts
**Impact on frequency control and stability**

**Generation-load imbalance event:**
- Loss of a single generation unit (273 MW)
- 5% of the demand covered with solar resources connected in the distribution network
- Colombian connected to Ecuador
- Grid 2023

Systemic loss of generation in the distribution system around 5% of the demand becomes a critical contingency. The operating frequency ranges for solar generation in the distribution network must be consistent with the operating requirements and frequency regulation mechanisms of the system.
Impact on frequency control and stability
Generation-load imbalance

**Generation-load imbalance event:**

- Loss of 200 MW of load
- 5% of the demand covered with solar resources connected in the distribution
- Colombian connected to Ecuador
- Grid 2023

Systemic loss of generation in the distribution system around 5% of the demand becomes a critical contingency. The operating frequency ranges for solar generation in the distribution network must be consistent with the operating requirements and frequency regulation mechanisms of the system.
Impact on frequency control and stability
Reserves - Inertia

High participation of DER, can displace conventional generation reducing inertia in the system and the availability of resources capable of providing frequency regulation services - greater vulnerability to major events

Reserve needs and ancillary services under review
Impact on Voltage control and stability
Voltage dip event - 115 KV with DER

Sample Case
• Demand 5700 MW
• Concentrated DER generation on eastern area
• System connected with Ecuador,
• Around 500 MW of DER generation disconnects due to lack of VRT
• Impact on system frequency
Envelope voltage-time curve at monitored busbars
• Case 2 (Caribbean) – Low thermal generation
• 3 phase faults at transmission and subtransmission lines
• Normal and delayed clearing times
Impact of VRT

System frequency after a 3 phase fault at 500 kV level considering VRT capability for DER
Impact on Voltage control and stability
High penetration levels of DER on the Caribbean Area

High levels of DER can lead to reactive power deficit situations in critical cases

In cases of low generation and low demand, high voltages difficult to control may arise

In cases of high thermal and wind generation and contingency N-1 at 500 kV, voltages can collapse

Contribution of reactive power by utility scale DER at shares above 20% of demand in the area would become important
An agreement with distribution system operator is required
DER requirements for the Colombian Power System
Prospective of System Operation
Measures to mitigate Impact of DER

- Forecasting
- Supervision
- Inclusion DER in calculating reserves

- Operating ranges in frequency
- Ramps

Operational actions to ensure sufficient inertia in the system

- FRT
- ReactivePower contribution