Challenges and Solutions for System Operations with high share of RE– Chile Experience

National Electric Coordinator (Chilean ISO)

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www.coordinadorelectrico.cl
Agenda

- National Electric Systems in Chile
- Electricity Market Framework, History and Context
- Main challenges in V-RE Integration
  - Lack of transmission capacity for RE
  - Interconnection the National Electric Grid
  - Ramping control for net load demand.
- Final Comments
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National Electric Coordinator – Chilean ISO

(Comodinador Eléctrico Nacional)

Independent technical organization in charge of operating (coordinating) the electric facilities in the national electric grid.

- Responsible for ensuring reliable, efficient operation of the power system, and for ensuring open access to the transmission systems
- Chilean ISO started up on January 1st, 2017 (Law 20,936, July 2016)
- Chilean ISO is the legal continuator of former CDECs (SIC and SING)
- Independent Board of Directors (5 members, 5-year period) responsible for steering and administering the organization
- Board Members elected by a Nomination Committee (National Energy Commission, Panel of Experts, Antitrust Tribunal, Public Executives Search Service) in a public recruitment process
Chile imports most of fossil fuel to produce electricity from international markets.
Electric System – SING
Northern Interconnected System (2016)

- Installed Capacity: 5,032 MW
- Energy Generated: 19,467 GWh
- Peak Demand: 2,555 MW
- Population: 1.1 Mill. (6.3%)
- Customers: 90% industrial

Capacity & Energy by Fuel Type

- Installed Capacity
- Energy Generated

Hydro
Coal
Diesel
LNG
Cogen
Wind
Solar

Installed Capacity
Energy Generated
Electric System – SIC

Central Interconnected System (2016)

- Installed Capacity: 16,837 MW
- Energy Generated: 53,906 GWh
- Peak Demand: 7,789 MW
- Population: 16.6 Mill. (92.2%)
- Customers: 70% regulated

Capacity & Energy by Fuel Type

45% of R.E. taking into account Large Hydro in SIC. 33% for both system SIC&SING
Electric Systems – Total

National System (2016)

- Installed Capacity: 22,045 MW
- Energy Generated: 73,877 GWh
- Peak Demand: 10,400 MW
- Population: 17.3 Millions
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**GENERATION AND ENERGY PRICES: HISTORICAL EVOLUTION**

- **First Natural Gas curtailment from Argentina**
- **Argentinean Natural Gas Crisis**
- **LNG (Quintero Plant)**

**Producción Energía** [GWh /mes]

**ENERGY SOURCES**
- Eólica
- Solar
- Otros (Biomasa-BioGas)
- Carbón
- Hidráulico
- GN
- GNL
- Petróleo

**Cmg Quillota 220 kV**
Chilean electricity market – Historical development (1)

- 1982

State-owned model
- Generation
- Transmission
- Distribution
All segments were public entities

1982

Private model
- Generation
- Transmission
- Distribution
Vertical integration was modified
Market introduction with locational marginal price scheme

2004-2006

Amendments

The “Short Law I”:
- Open access regulation
- It creates Expert Panel
- No transmission charges for non-conventional small projects < 9 MW

The “Short Law II”:
Tenders distribution companies supply (end-users)
Chile adopted a non-subsidiary model for the integration of renewables.

- **2008**
  - **Renewable Energy Law version 1**
    - Introduction of a renewable portfolio standard: 10% by 2024 (NCRE).

- **2012 - 2013**
  - **Renewable Energy Law version 2**
    - Increment on RPS target: 20% by 2025 (NCRE)
    - Net-metering Law.

- **2016**
  - **Transmission and only one Coordinator (Chilean ISO)**
    - Robust Transmission to avoid constrains.
    - Charged to demand (prorate)
    - A.S. Market (check competitive conditions)
THE DEVELOPMENT OF NCRE

Annual generation 2008

1567 GWh

- Hidro 40.7%
- Carbón 27.1%
- Diesel 24.2%
- GNL 5.2%
- ERNC 2.9%

Annual generation 2016

7841 GWh

- Hidro 24.2%
- Carbón 44.2%
- Diesel 2.6%
- GNL 16.3%
- ERNC 12.5%

COMPLIANCE THE TARGET
2010-2016

The annual target has been exceeded by projects developed under market conditions.
Tenders Process for supply energy to Distribution Companies

- Introduction of the so-called ‘hourly blocks’, with a significant impact on bidding prices.
TENDERS PROCESS
Regulated customer
In 2016 52% of the energy tendered was awarded to NCRE

Average price 2016 = 47.6 US$/MWH
(include a record bid for Chile PV project=29 US$/MWh Block B)

<table>
<thead>
<tr>
<th>Year</th>
<th>Número oferentes</th>
<th>Porcentaje ERNC</th>
<th>Energía adjudicada (GWh/año)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>2</td>
<td>0%</td>
<td>3.900</td>
</tr>
<tr>
<td>2014</td>
<td>18</td>
<td>30%</td>
<td>2.705</td>
</tr>
<tr>
<td>2015</td>
<td>38</td>
<td>100%</td>
<td>1.200</td>
</tr>
<tr>
<td>2016</td>
<td>84</td>
<td>52%</td>
<td>12.403</td>
</tr>
</tbody>
</table>

USD/MWh

US$/AÑO
INTERNATIONAL CONTEXT

Bidding process

Fuente: IRENA, Nethinking Energy 2017
Electricity Market Framework

Ministry of Energy

National Energy Commission (CNE)
- Regulatory body
- Laws, decrees, norms
- Set rates

Fuels & Electricity Superintendency (SEC)
- Sanctioning body
- Interprets regulations
- Norms compliance oversight

National Electric Coordinator (Chilean ISO)

Other organizations:
- Panel of Experts
- National Economic Prosecution Office (FNE)
- Transparency Counsel

Generation Companies

Transmission Companies

Distribution & Large Customers
Wholesale Energy, Capacity & AS Markets

- Chilean ISO defines day-ahead generation schedule based on economic dispatch
- LMP from economic dispatch is based on declared variable costs (LMP settlement ex-post)
- Chilean ISO determines energy balances by differences (contracted vs. actual generation priced at LMP)
- Competitive long-term energy bids for regulated customers conducted by the CNE
- Capacity payments based on plants’ availability during peak demand
- Ancillary services will transition from cost-based to auction-based for balancing

- Proportionally charged to demand
- Tariff based on tender process for new transmission projects
Wholesale Marginal Cost & Tariffs

Rates 2016:

- Capacity: 100,000 USD/MW/Yr.
- End customer: 200 USD/MWh (70% G, 8% T, 22% D)
- Large Customers: 62 USD/MWh
Transmission Sector

- The transmission system was separated into three segments: National, Zonal and Dedicated Transmission segments.
- Centralized planning (CNE-Chilean ISO).
- System expansions based on competitive bidding process.
- Bidding process administered by Chilean ISO.
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Potential Renewable Energy in Chile

Chile has enormous potential, more than 1,865 GW of wind, solar and hydro energy, and probably 2,000 or more MW geothermal power and 2,000 MW of biomass.

FLEXIBILITY CHALLENGES

1) Conventional power plant operation regime
2) Environmental Regulations
3) Others flexibility sources
CHALLENGE INTEGRATION NCRE
Handle lack of transmission capacity for RE

In the northern part of SIC (800 km, 220 kV system):

Local Demand: 1000 MW

Install Capacity (Wind+PV): 2200 MW

Coal Power generation: 750 MW (5 units 150 MW, minimum load (40%) 25% to 36%)

Transmission capacity North-->South: 224 MW, N-1 criteria.

In normal operation it is necessary to order curtailments.

“zero” marginal cost during day hours.
The main objective of the scheme is to increase the use of transmission capacity from NORTH → SOUTH, allowing maximum generation from NCRE sources. (N-1 to near “N”)

Reducing operation costs of the whole system without affecting security constraints.

A design for an automatic scheme for reduction/disconnection of power generation is available. Basically, the scheme will allow transmission levels reduction under contingencies in the Northern SIC and a fine-tuning of power transmission levels under normal operation.

Lack of transmission capacity for RE
CHALLENGE: INTERCONNECTION THE GRIDS
Coordination, Security, Stability, Reactive power control, Variability of power flows

Los Changos 500 > Cumbre 500

Cumbre 500 > Cardones 500

Cardones 500 > Maitencillo 500
CHALLENGE: INTERCONNECTION THE GRIDS
Coordination, Security, Stability, Reactive power control, Variability of power flows.
CHALLENGE: INTERCONNECTION THE GRIDS
Coordination, Security, Stability, Reactive power control, Variability of power flows.
RAMPING CONTROL

Summer day: 2021

Potencia (MW)

0  3  6  9  12  15  18  21  24

Disminución en 2 horas:
800 MW (Ley ERNC)
1,200 MW (Ley ERNC+30%)

Aumento en 2 horas:
1,200 MW (Ley ERNC)
1,500 MW (Ley ERNC+30%)

30%
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Final Comments:

- The fast integration of renewables energy in the Chilean power system is bringing new challenges in order to keep the reliability standards and guarantee an efficient operation.

- The interconnection SING-SIC (2017-2018) will be a valuable support to face these challenges (flexibility from hydro reservoir) but it could be not enough. We have to think, for instance, in redesign the A/S market

- National and regional control centers

- System Resilience (forest fires, hydrology variability, drought conditions prolonged 7 years)

- Integration of high levels of renewables (high potential wind&solar)

- Centralized forecasting V-RE, National AGC, situational awareness

- NCRE: Grid friendly

- Implementing new functions (Law 20,936)