Flexible Transmission Expansion in the Chilean Electricity Market

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Agenda

- SIC-SING Interconnection and the National Power System
- Transmission Planning Process
- New Transmission Planning Criteria
- Flexibility in Transmission Expansion
- Long Term Vision in Transmission
We are an independent technical public-service organization that coordinates the operation of the national electric grid, ensuring a secure, reliable and economic energy supply, and guaranteeing open access to the transmission systems.
SIC-SING INTERCONNECTION PROJECT

500 kV Transmission lines

140 km
400 km
189 km
135 km
212 km
408 km

Com.2017
KAPATUR 220 kV

Com.2020

Com.2017

Com.2017-2018

transelec
TEN
ISA INTERCHILE

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SIC-SING INTERCONNECTION PROJECT

- D/E Angamos (Gener)
- S/E Kapatur (STN/Saesa)
- S/E Kelar (Tamakaya)
- S/E SIC (Gener)
- S/E Nueva Diego de Almagro (Gener)
- S/E Kimal (SATT/Saesa)
- S/E Nueva Cardones (Interchile)
- S/E Los Changos (TEN)
- S/E Nueva Maitencillo (Interchile)
- S/E Cumbres (TEN)
- S/E Nueva Pan de Azúcar (Interchile)
- S/E Nueva Diego de Almagro (Celeo Redes)
- S/E Los Changos (Celeo Redes)
- S/E Nueva Diego de Almagro (Celeo Redes)
- S/E Nueva Diego de Almagro (Celeo Redes)
- S/E Polpaico (Transelec)

- Proyectos TEN
- Proyectos Transelec
- Proyectos Interchile
- Proyectos Saesa
- Proyectos Engie
- Proyectos Celeo Redes
- Instalaciones Existentes

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NATIONAL POWER SYSTEM in 2018

Installed Capacity: 24,000 MW
Peak Demand: 11,000 MW

NPS 3,100 km

- Hidráulica: 516 MW (2%)
- Carbón: 7,097 MW (29%)
- Gas: 4,859 MW (20%)
- Diesel/Fuel oil: 3,762 MW (16%)
- Solar: 3,733 MW (15%)
- Eólica: 2,789 MW (12%)
- Otros: 1,333 MW (6%)

Fuente: Comisión Nacional de Energía

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Transmission Planning and Delivery (from 2017 on)

Long-Term Energy Planning Process
(Developed every 5 years by Ministry of Energy)

ANNUAL TRANSMISSION PLANNING PROCESS

Coordinator proposes Transmission Projects to CNE

CNE Transmission Planning Study and Evaluation

Experts Panel resolves discrepancies

Enactment of Transmission Expansion Decree

Transmission Projects Tendering (National and Zonal)

Upgrade and Expansion projects tendered by the Coordinator (National and Zonal transmission)

Market agents propose transmission projects to CNE
Transmission Planning Methodology

Phase 1: Projection of main variables

Demand Forecasting

Phase 2: Analysis of expansion requirements

Generation Scenarios

Diagnosis of use of the Transmission System

Definition of alternative projects

Power system studies

Projects conceptual engineering

• Equipment selection
• Unilinear diagrams
• Plant diagrams
• Project schedule
• Investment valuation

Project economic evaluation:

With and without the project

Phase 3: Evaluation and project definition

Transmission Expansion projects Proposal

Definition of alternative projects

Power system studies
New Transmission Planning Criteria

• Minimize supply **risks**, considering events, such as:
  - cost increase or **unavailability** of fuels
  - delays or **unavailability** of energy infrastructure
  - **Natural disasters** or extreme **hydrology conditions**

• **Promote the offer and facilitate competition** in order to supply consumers at **minimum price**

• **Economically efficient** and **necessary** projects in the different energy scenarios

• **Modification of existing** transmission facilities in an efficient way

Transmission planning must include **roominess** and **redundancies** in order to incorporate all previous criteria
New Transmission Planning Criteria

1. Adequacy:
   - CAPEX < NPV[Δ(OPEX+CENS)]

2. Security of Service: N-k criteria
   - Resilience: resist LPHI events

3. Competition: Open Access to the Grid

4. Sustainability: Efficient use of Territory

5. Robustness: Long Term Vision and Flexibility

- Minimize supply risks, considering events, such as:
  - cost increase or unavailability of fuels
  - delays or unavailability of energy infrastructure
  - Natural disasters or extreme hydrology conditions

- Promote the offer and facilitate competition in order to supply consumers at minimum price

- Economically efficient and necessary projects in the different energy scenarios

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Flexibility in Transmission Expansion

1. Adequacy:
   - CAPEX < NPV[Δ(OPEX+VOLL)]

2. Security of Service: N-k criteria
   - Resilience: resist LPHI events

3. Competition: Open Access to the Grid

4. Sustainability: Efficient use of Territory

5. Robustness: Long Term Vision and Flexibility

Flexible Transmission:
- Robust Planning
- Technology
- Smart Grid
Flexible Transmission: Robust Planning

- Anticipatory planning: make decisions under uncertainties
- Stripes for new transmission lines with Strategic Environmental Evaluation
- Roominess in the design of new transmission infrastructure
- Upgrade and uprate of existing lines and substations
- Zonal transmission:
  - Access to cities and towns
  - Shared services infrastructure
  - Distributed generation
Flexible Transmission: Technology

- Transmission support associated to Variable Renewable Energy:
  - Size and location of reserves
  - Inertia constraints
  - Battery Energy Storage Systems – BESS:
    - Expansion deferral
    - Congestion relief

- Flexible AC Transmission Systems: FACTS

- HVDC:
  - Long lines with LCC vs VSC
  - Multi-terminal option
  - Lines vs Cables
  - Back-to-Back Converters
FACTS: Reactive power compensation

Status: In operation

- SVC Plus Diego de Almagro: -100 / +140 MVAr
- SVC Maitencillo: -28 / +24 MVAr
- SVC 1 Pan de Azúcar: -28 / +24 MVAr
- SVC Polpaico: -65 / +100 MVAr
- SVC Puerto Montt: -40 / +70 MVAr
- SVC Domeyko: -50 / +120 MVAr
- SVC Cardones: -60 / +100 MVAr
- SVC 2 Pan de Azúcar: -28 / +24 MVAr
- STATCOM Cerro Navia: -65 / +140 MVAr

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FACTS: Reactive power compensation

2017 Recommended project (under tendering)

NUEVA MAITENCILLO 500
- Overvoltage
- Voltage variability

NUEVA PAN DE AZÚCAR 500

POLPAICO 500

Proposal:
- Modification of series compensation
- Shunt reactors
- Reactive power variable compensation

Overvoltage
Voltage variability

TCR 200 MVAr
inductivos

FC 5° armónica
= 50 MVar capacitivos

FC 7° armónica

SVC +50/-150 MVAr
FACTS: Reactive power compensation

Recommended project - **ALTERNATIVE**

- Overvoltage
- Voltage variability

**Proposed project**

- Modification of series compensation
- Shunt reactors
- Reactive power variable compensation
**FACTS: Phase-Shifting Transformers**

**Tocopilla Substation**
T1: 100 MVA – 110/110 kV
T2: 100 MVA – 110/110 kV

**Objective**: Control power flows in specific lines of the power system.

**Cerro Navia Substation**
T1: 350 MVA – 220/220 kV
T2: 350 MVA – 220/220 kV
FACTS: Fixed Series Compensation

1x345 kV Andes-Salta
Andes: 36% (408 km)

2x500 kV Los Changos-Cumbre
Los Changos: 65/2% (400 km)
Cumbre: 65/2% (400 km)

2x500 kV Cumbre-Nueva Cardones
Cumbre: 55% (189 km)

2x500 kV Nueva Maitencillo-Nueva Pan de Azúcar
Nueva Pan de Azúcar: 55% (212 km)

2x500 kV Nueva Pan de Azúcar-Polpaico
Nueva Pan de Azúcar: 53% (408 km)

2x220 kV Colbún-La Candelaria
La Candelaria: 60% (214 km)

1x500 kV Ancoa-Alto Jahuel C1
Ancoa: 56% (241 km)

1x500 kV Ancoa-Alto Jahuel C2
Ancoa: 58% (257 km)

2x500 kV Ancoa-Alto Jahuel C3 and C4
Ancoa: 44% (256 km)

1x500 kV Charrúa-Ancoa C1
Ancoa: 50% (183 km)

1x500 kV Charrúa-Ancoa C2
Ancoa: 53% (196 km)
Flexible Transmission: Smart Grid

System Monitoring, Control and Protection – Conceptual View

Wide Area – WAMPAC: with PMU, DLR

Extended Control: WAC-SIPS-RAS with PMU, DLR, IED

Control and Protection: IED
Back up: PMU, IED

Local (logic)
Remote (Comm. aid)

Local protection: IED
First adjacency: IED
Principal (no delay)
Local backup (with delay)

WAMPAC: Wide Area Monitoring, Protection and Control
DLR: Dynamic Line Rating / PMU: Phasor Measurement Unit
SIPS: System Integrity Protection Scheme / RAS: Remedial Action Scheme
IED: Intelligent Electronic Device
Long Term Vision in Transmission
Long Term Vision in Transmission

Alternative 1

Polpaico
Lo Aguirre
Cerro Navia
El Salto
Chena
Los Almendros
Ancoa
Alto Jahuel
Entre Ríos
Charrúa

Alternative 2

Polpaico
Lo Aguirre
Cerro Navia
El Salto
Chena
Los Almendros
Ancoa
Alto Jahuel
Entre Ríos
Charrúa

Possible international interconnection

Argentina

Gran Mendoza

C1 C2 C3 C4

500 kV

220 kV

Alternative 1

Alternative 2

Possible international interconnection
Long Term Vision in Transmission

Charrúa
Mulchén
Rio Malleco
Cautín
Ciruelos
Valdivia
Pichirrupulli
Rahue
Tineo
Puerto Montt
Melipulli
Nueva Ancud

500 kV
220 kV
Alternative
In Summary

- Coordinador face current challenges associated to:
  - the interconnection of SIC and SING to create a unique (long) national power system (3,100 km)
  - implementing the new transmission planning and delivery processes
  - developing and applying the new transmission planning criteria
- Flexibility in transmission expansion is reflected via robust planning, technologies and smart grids
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