A Surplus Based Framework for Cross-Border Electricity Trade in South America

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Introduction

- Over the last decade, South America has experienced a robust economic growth, with electricity consumption per capita increasing at a rate of 3,3% per year
- During that time, the main energy resource – hydroelectricity - has been quite unstable, with severe droughts in Chile, Brazil, and Colombia. Also new large hydro projects have been either postponed or abandoned due to social and environmental concerns.
- As a result, the region increased its usage of fossil fuels.
- Increasing energy demand, growing risk from hydropower generation, and increasing emissions, have put significant pressure to start considering alternative ways to generate energy.

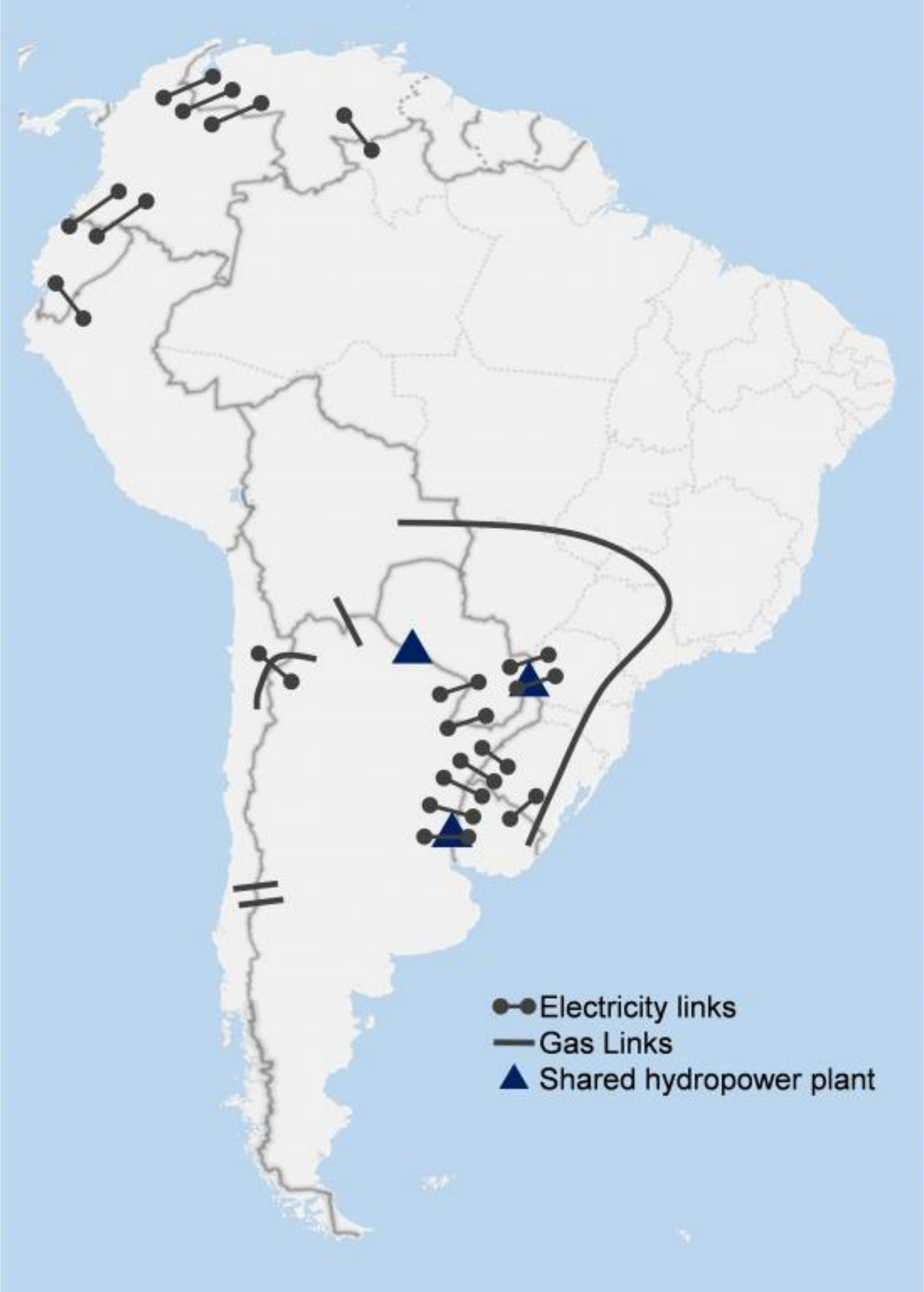
Motivation and Goal of the Paper

- Cross-border electricity trade could be a cost-effective alternative to deal with the energy challenges in South America. However, recent history is full of mistrust and frustration from various unsuccessful integration attempts.
- This paper presents a proposal for the treatment of short-term electricity exchanges among countries in South America, as a trust-building effort to set the basis for a later continent wide integration.
- For this purpose, the exchange of energy between Chile and its neighboring countries is simulated, based on real data from the operation of the Chilean electricity system.

Cross-Border Electricity Trade in South America

- Globally, the international trade of electricity is about 3% of the total production (2% in South America). A small figure compared to other energy sources (for example, 64% for oil according to Oseni and Pollitt, 2014).
- In the region, there are only two areas where this occurs actively:
  - The northwest part of the continent, which includes Colombia, Ecuador, and Venezuela, and,
  - The southeast part of the continent, which includes Brazil, Paraguay, Argentina, and Uruguay (Yepez-García et al, 2010).
- In the case of Chile and Argentina, there is one interconnection, but is currently not being used. There is no interconnection between Chile and Perú.

Existing interconnections among South American countries



Benefits of Regional Interconnection and Electricity Trade

- **Reduction in generation costs due to an optimal resource allocation for power generation.**
- Increase in security of the power systems as having access to a larger grid and a greater number of generation sources increases the diversity of the generation system.
- Increase in competition through the availability of electricity from more market players and sources.

A Surplus Based Framework for Cross- Border Electricity Trade

- A complete regulatory framework would be to establish a structure for regional electricity market, which would allows the optimization of the generation capacity, bringing benefits for the whole region. In this sense, the current proposal is just a first step in this task.
- However, any effort in this area requires, at least, the generation of the necessary incentives for the investment in transmission infrastructure.
- The basic components of an exchange framework are: a definition of the short-term markets, dealing with congestion rents, the remuneration of the transmission system, and the treatment of energy in transit.

Simulation Methodology

- For the simulation of the framework, the monthly operation is considered using the same rules already existing in the Chilean market, simulated using a Plexos unit commitment from EnergyExemplar.
- The exports and imports are modeled as:
  - For exports as an equivalent load at the boundary node.
  - For imports as an equivalent generator at the boundary node, with a variable cost.
- The benefits from the exchanges are divided in equal parts between the exporting and importing countries, and used to pay for part of the transmission system, thus benefiting consumers.
- The results from the simulations include: transmission usage, generation marginal & average cost, total cost of operation and the composition of the energy matrix.

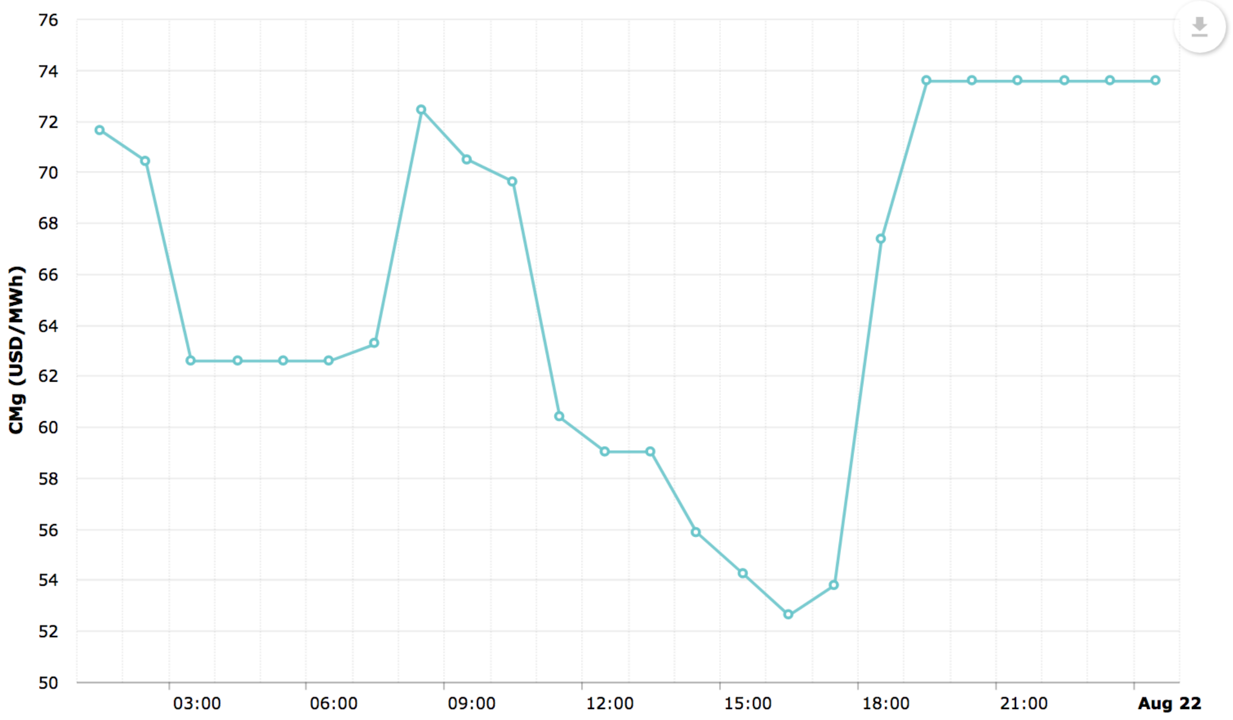
Results

- We simulated three energy trade scenarios:
  - Import from Perú to Chile
  - Export from Chile to Argentina
  - Import from Perú to Chile, and, export from Chile to Argentina (combination of the first two scenarios).

Results: Imports from Perú to Chile

- Import simulations from Perú considered that Chile has low production costs during the sunlight hours due to the high penetration of solar energy, while Perú presents moderate to low energy costs during the "no-sunlight" hours from its energy matrix, which is based on natural gas and run-of-river hydropower.

- Therefore, the import of energy from Peru would occurred in two time slots: from 0:00 to 8:00 hours, and from 17:00 to 23:59 hours.



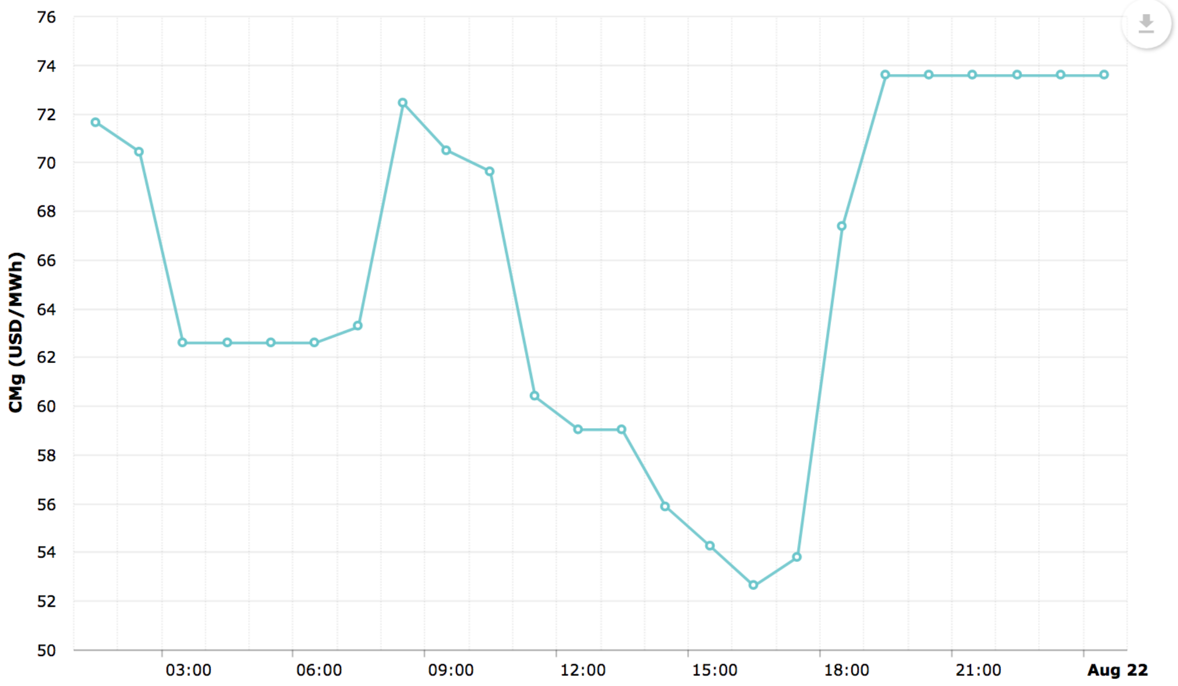
Results: Imports from Perú to Chile

- The imports of energy from Perú allow Chile to substitute diesel burning generators with imported energy, which would improve the economic and environmental indicators of the Chilean energy matrix.
- The results of the simulation show that daily operating cost decreases from 1.8 to 1.64 million dollars (8.9% less). The average hourly cost of the system decreases from an average of 34.8 USD/MWh to an average of 31.7 USD/MWh (8.7% less).
- The import of energy from Perú would generate an Annual Total Benefit of the order of 10.37 million dollars, of which 5.2 million dollars are a benefit for Chile.
- This order of magnitude is not negligible since it is equivalent to 10% of the annual value of the transmission system of the northern region of the Chilean Interconnected System (2016).

Results: Exports from Chile to Argentina

- The simulations of energy exported to Argentina consider that Chile has low production costs during the sunlight hours due to the high penetration of solar energy, while Argentina has a high energy cost during the day, due to the usage of diesel units to satisfy its demand.

- For that reason, the export of energy to Argentina would take place between 8:00 a.m. and 5:00 p.m.



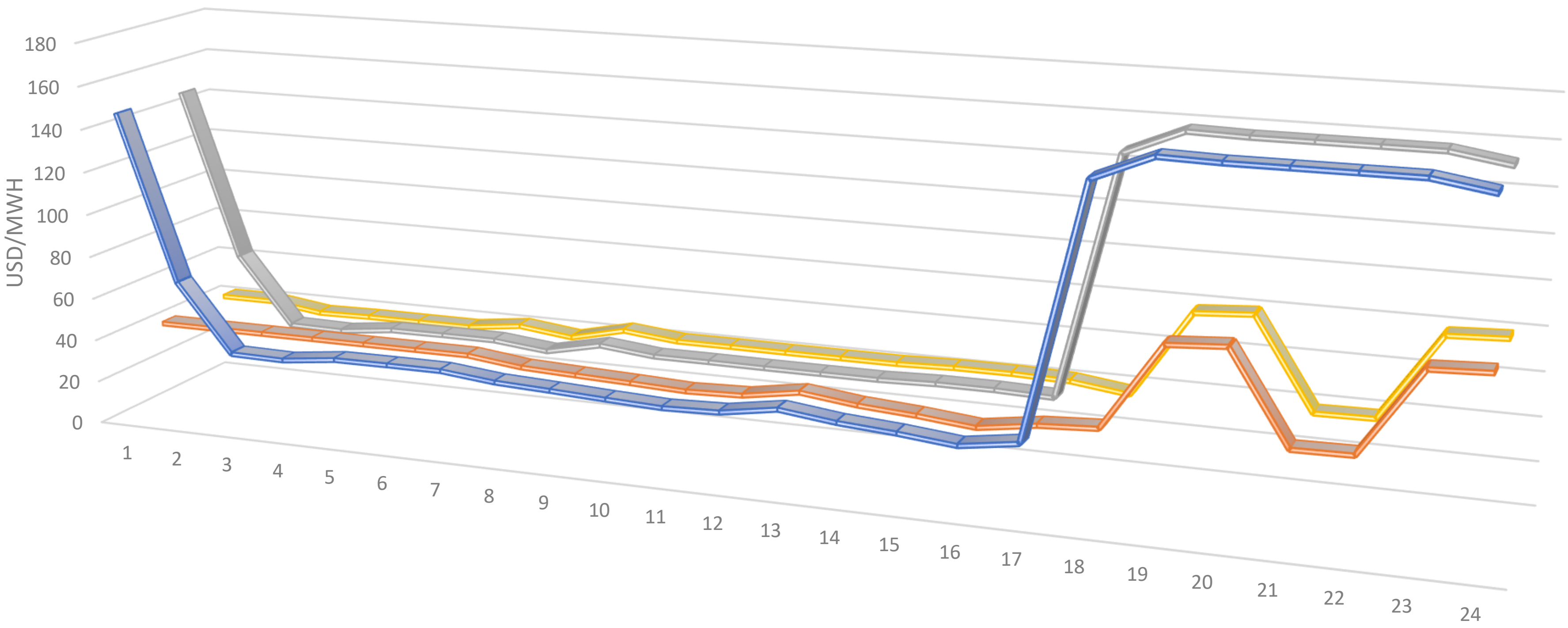
Results: Exports from Chile to Argentina

- The results of the simulations show that the daily cost of operation would increase from 1.80 to 1.86 million dollars (3% increase) and the average hourly cost of the system would increase from 34.8 USD/MWh to 35 USD/MWh (0.7% increase).
- The export of energy to Argentina would generate an Annual Total Benefit of the order of 16.82 million dollars per year, of which 8.4 millions correspond to benefit for Chile.
- This order of magnitude is not irrelevant since it is equivalent to 16% of the transmission system of the northern region of the Chilean Interconnected System (2016).

Results: Imports from Perú to Chile & exports from Chile to Argentina (combination)

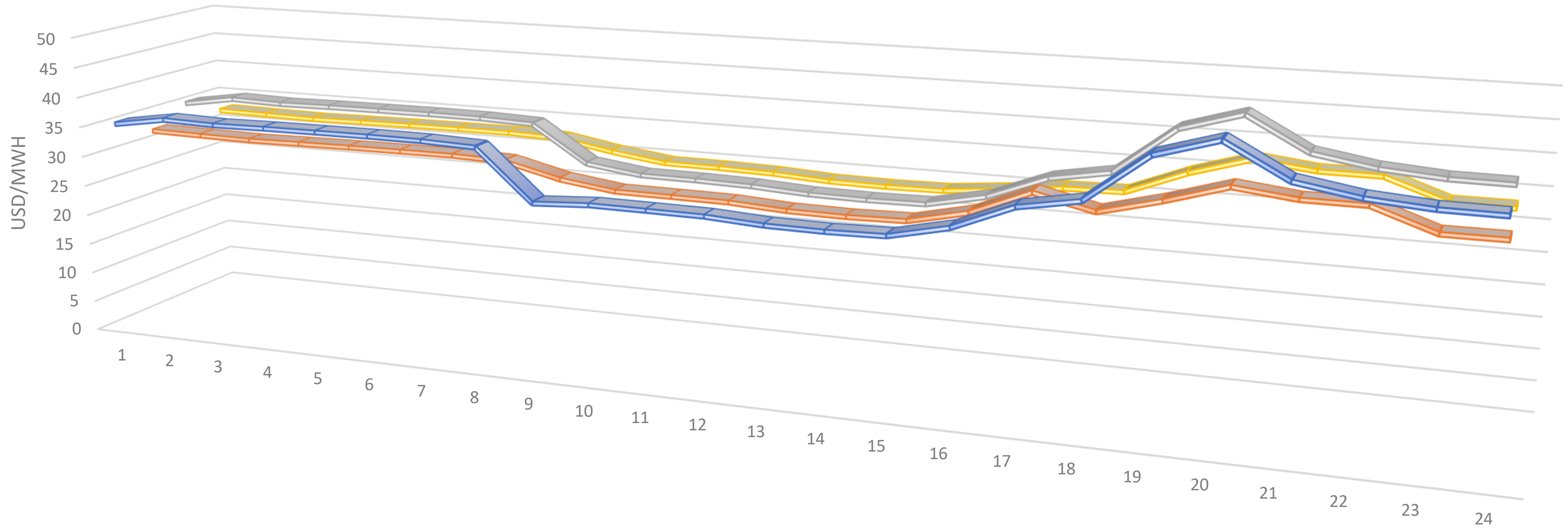
- The results show that daily operating costs decrease from 1.80 to 1.68 million dollars (a 6.8% decrease). The average hourly cost of the system would go from 34.8 USD/MWh to 31.6 USD/MWh (9% decrease).
- The export and import of energy with neighboring countries, under the proposed regulatory framework, would generate an Annual Total Benefit in the order of 40.6 million dollars per year, of which 20.3 millions correspond to a benefit for Chile.

Marginal cost of the system



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Base	147	69	38	37	40	40	40	38	37	35	34	35	39	36	34	32	36	151	162	161	161	161	161	157
Import	40	40	40	40	40	40	40	37	36	35	34	35	39	36	34	32	36	37	77	78	37	37	77	78
Export	147	69	38	37	40	40	40	38	43	40	40	40	40	40	41	41	40	151	162	161	161	161	161	157
Import and Export	40	40	37	37	37	37	40	37	43	40	40	40	40	40	41	41	40	37	77	78	37	37	77	78

Average costs of the system



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Base	35	37	36	37	37	37	37	36	28	29	29	28	28	28	28	30	34	36	43	46	41	39	38	38
Import	32	32	32	32	32	32	32	32	30	29	29	28	28	28	28	30	34	32	34	37	36	36	33	33
Export	35	37	36	37	37	37	37	36	30	29	29	29	28	28	28	30	34	36	43	46	41	39	38	38
Import and Export	32	32	32	32	32	32	32	32	30	29	29	29	28	28	28	29	30	31	34	37	36	36	33	33

Composition of the Energy Matrix

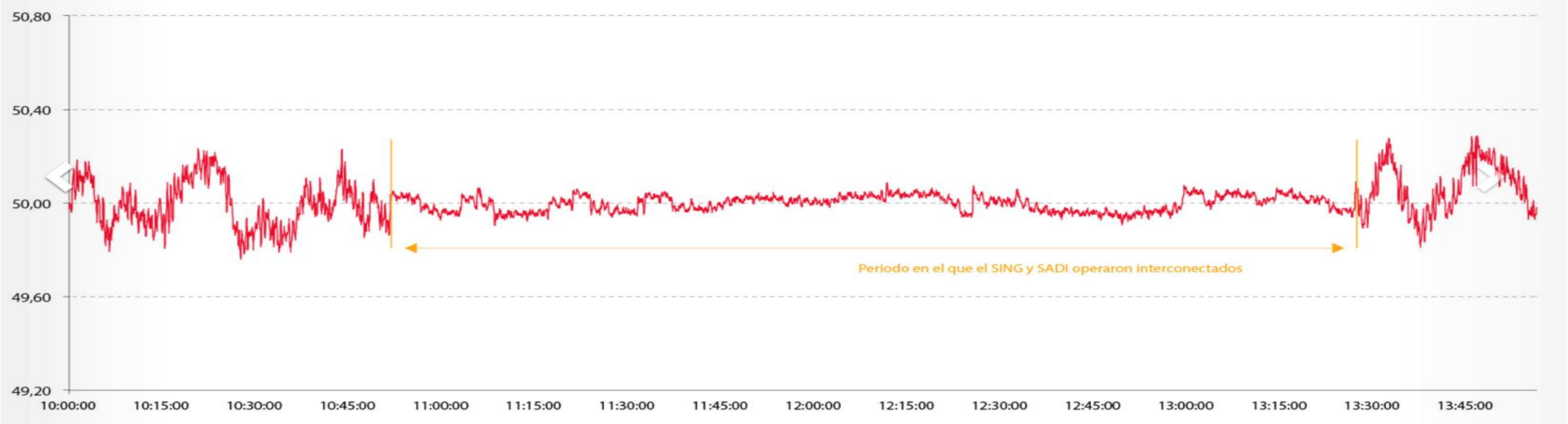
Technology	Scenario Base	Scenario Import	Scenario Export	Scenario Imp + Exp
Diesel	4%	1%	4%	1%
LNG	12%	12%	12%	12%
Hidro	0%	0%	0%	0%
Coal	77%	76%	78%	77%
Solar PV	5%	5%	5%	5%
Wind	1%	1%	1%	1%
Import	0%	4%	0%	4%
TOTAL	100%	100%	100%	100%

Conclussions

- Currently, regulation in most countries in South America does not consider the existence of regional electricity markets, nor the possibility of exchanges with neighboring countries
- This paper presents a proposal for the treatment of short-term electricity exchanges between countries as a trust building effort
- The results of simulations show that this simple regulatory proposal is not only feasible but also that it would reduce the marginal energy costs and the average operating cost of the system
- The international exchange of energy would allow a more efficient use of energy resources of the countries, without decreasing the security and quality of service, or sacrificing the operating principle at minimum cost prevailing today in the national regulations.

Site note: Impact in Security of the Chilean Northern System

- The integration has very important “system” byproducts:
  - Chile´s system gets a smoother frequency while interconnected (SADI is ten times bigger than the Chile´s northern system)



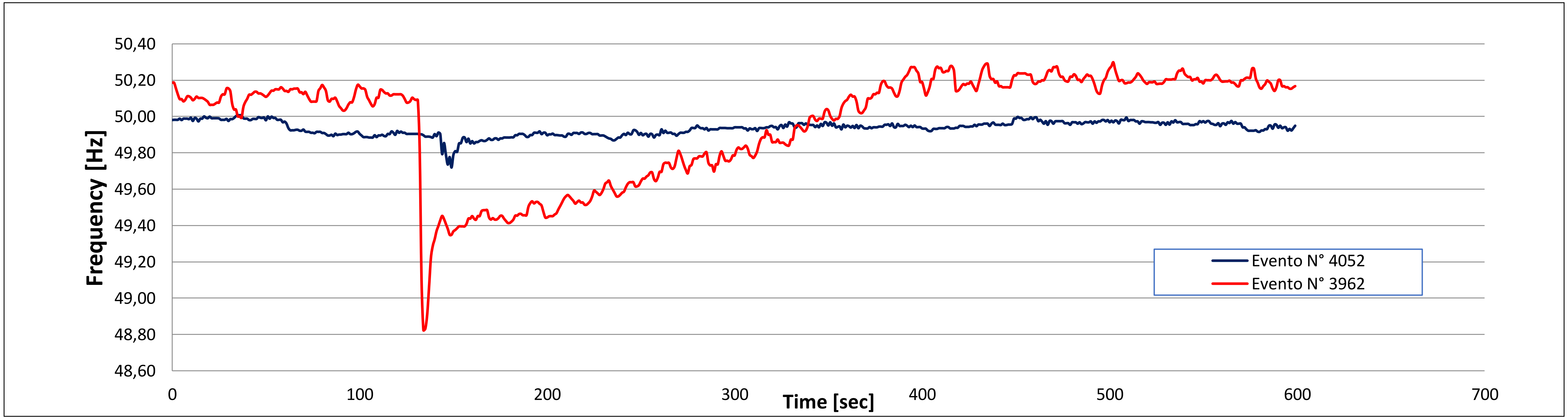
Side note: Impact in Security of the Chilean Northern System

Event 3962 (Nov. 5th 2015): Fault in Generator Angamos 1 with 263 MW

- Frequency reached 48.8 Hz
- Loss of 106.2 MW of load → Unserved load 48.6 MWh

Event 4052 (Feb. 22nd, 2016): Fault in Generator Angamos 2 with 253 MW

- Frequency reached 49.71 Hz → No load shed



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