Cross-border Sharing of Reserve and Balancing Resources for Argentina and Chile

CESI
Shaping a Better Energy Future

with the scientific contribution of the

enel Foundation

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Aim of the study

- The activity aims to assess the variation of costs and benefits for the system deriving from the reduction of the Net Transfer Capacity (NTC) between Chile and Argentina, leaving some transmission capacity to the sharing of resources for balancing and ancillary services

- The operation of Chile-Argentina interconnected system is simulated by means of probabilistic analyses evaluating overall cost/benefit from a shared management of ancillary services and balancing resources between countries

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Reserve requirements

- The balance between demand and generation in an electric power system must be maintained in the various time frames of operation; usually, automatic controls (primary, secondary and tertiary control) keep the balance up in the different levels using the power system reserve

- System reserve must ensure that there is enough available operating reserve to guarantee the reliability of the system in different timescales. The amount of required reserve has to be large enough to face either forecasts errors or contingencies like the loss of generating units or interconnections

- Operating Reserve is any additional capacity (generation and responsive load availability) above that needed to meet actual load demands and available either on-line or on-standby so that it can be called on to assist if load increases or generation decreases, due to unpredictability or variability of the conditions

Reserve requirements

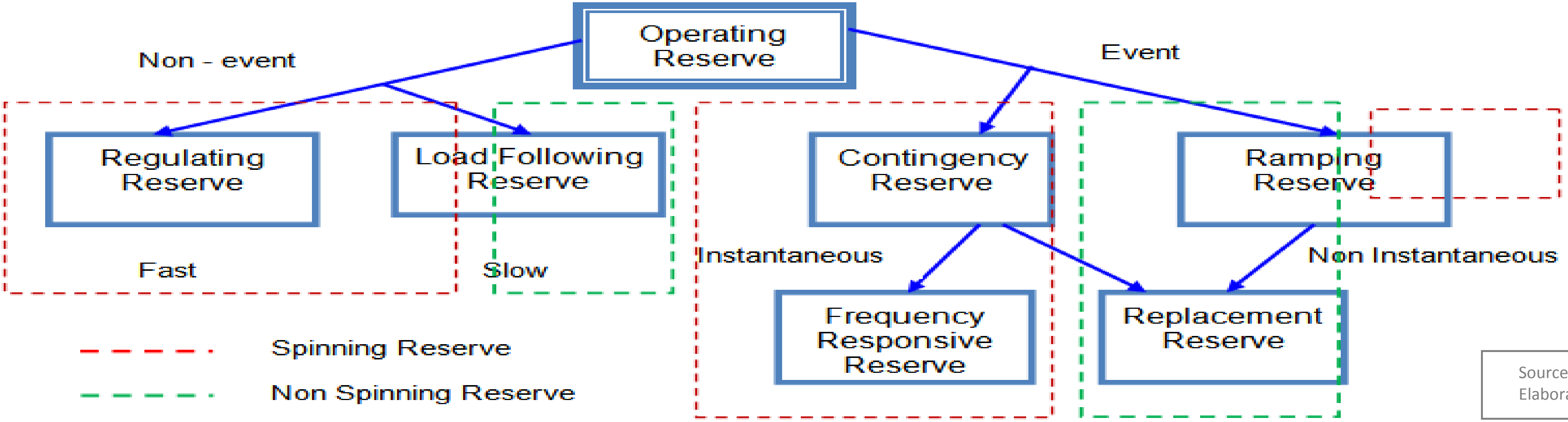
Based on power plants condition, the Operating Reserve is divided into:

- Spinning Reserve: it should be able to restore any frequency deviation to an acceptable level in the event of a loss of generation or a mismatch between generation output and demand, without any load-shedding
- Non-Spinning Reserve: off-line generators able to be synchronized quickly to fill the gap in energy balance restoring the frequency back to its nominal level. In addition, the non-spinning reserve service is available for the assistance in replacing reserve used during a severe instantaneous event

Both reserves can cover both non-events and events:

- Non-Event Reserve: capacity available for assistance in active power balance during normal conditions, or those that occur continuously. Non-events are continuous events that happen so often they are not distinguishable from one another
- Event Reserve: capacity available for assistance in active power balance during infrequent events that are more severe than balancing needed during normal conditions

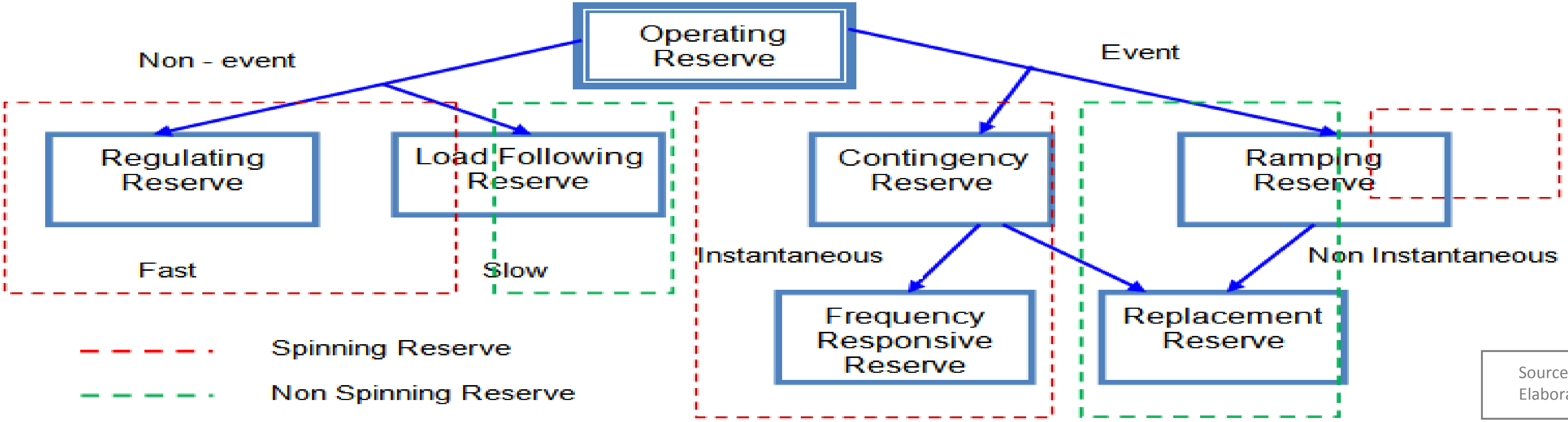
Reserve requirements



Source: NREL
Elaborated by CESI

- This study focuses on the variation of requirement and cost relevant to spinning reserve needed in electric power systems with high VRES penetration mainly for fast regulation and frequency control after contingencies
  Spinning reserve represents an actual cost for the system because some generators must operate not according to the best merit order; non spinning reserve has a lower economic impact because generators are still and ready to start

Reserve requirements



Source: NREL
Elaborated by CESI

- The effect of mutual support between countries for balancing and ancillary services is analysed. The possibility to exchange power might reduce the reserve requirement, allowing to reduce the costs associated to spinning generators
- The simulation model calculates these reserves applying the most popular statistical method, in which the variability/forecast errors of VRES generation are combined with those related to the load and with the occurrence of the most critical events in the system (e.g. loss of the biggest generation unit in service)

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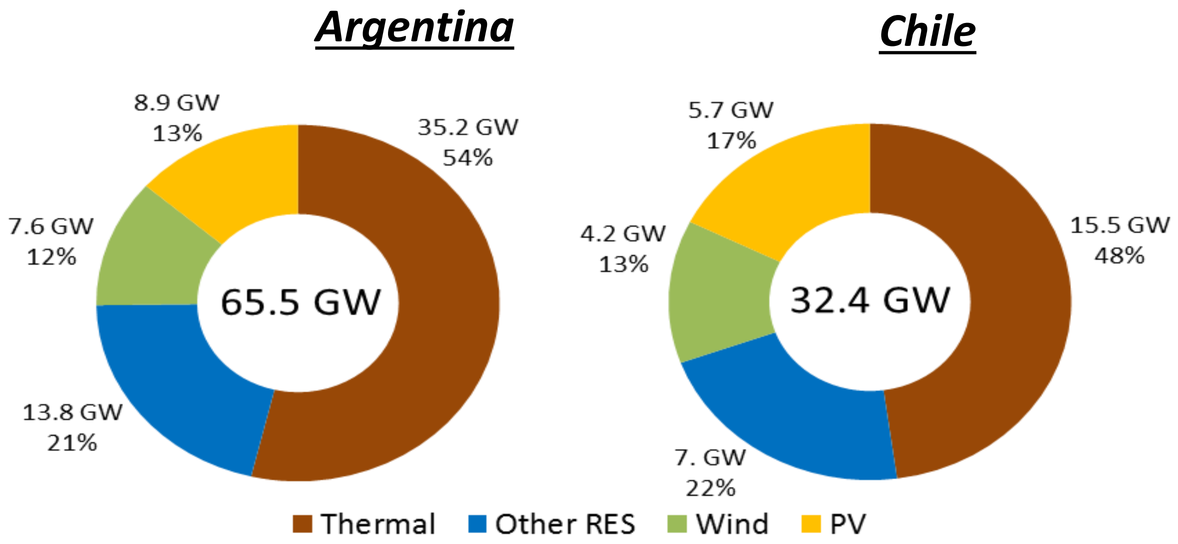
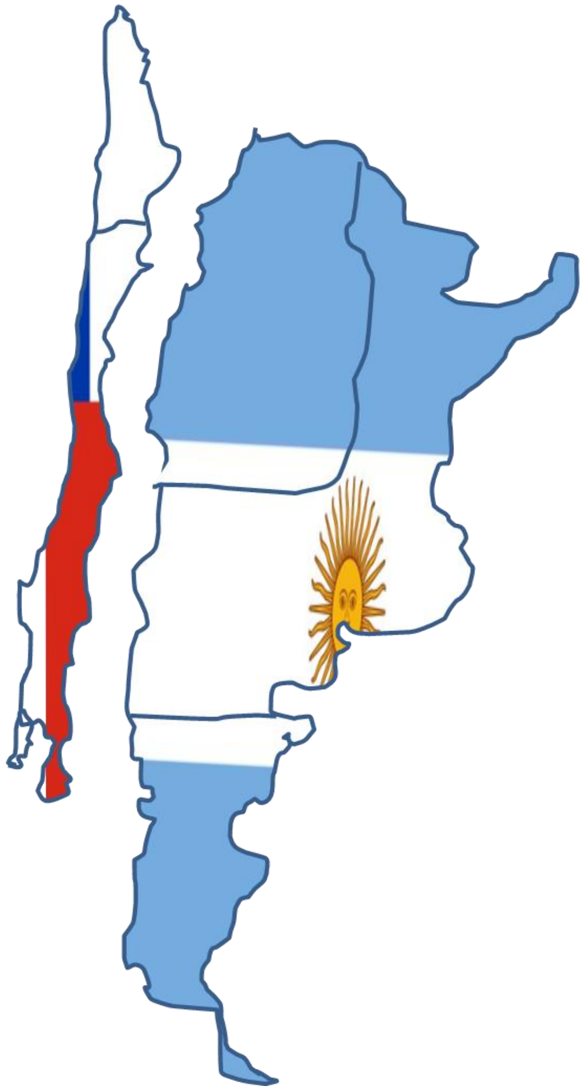
Reference scenario

- Argentina and Chile at target year: 2030
- “Reference Scenario” defined based on best available information by Ministries, Authorities and System or Market Operators (2016-2017):
  - ✓ Load considered in the countries
    ARG: 230 TWh/year - CHI: 109 TWh/year
  - ✓ Generation:





Electric power system model

Detailed network model

- Detailed representation of HV transmission network (≥110 kV) of Chile and Argentina

Interconnections Chile and Argentina

Existing 345 kV line Andes (CHI) - Cobos (ARG), with physical capacity up to 600 MW

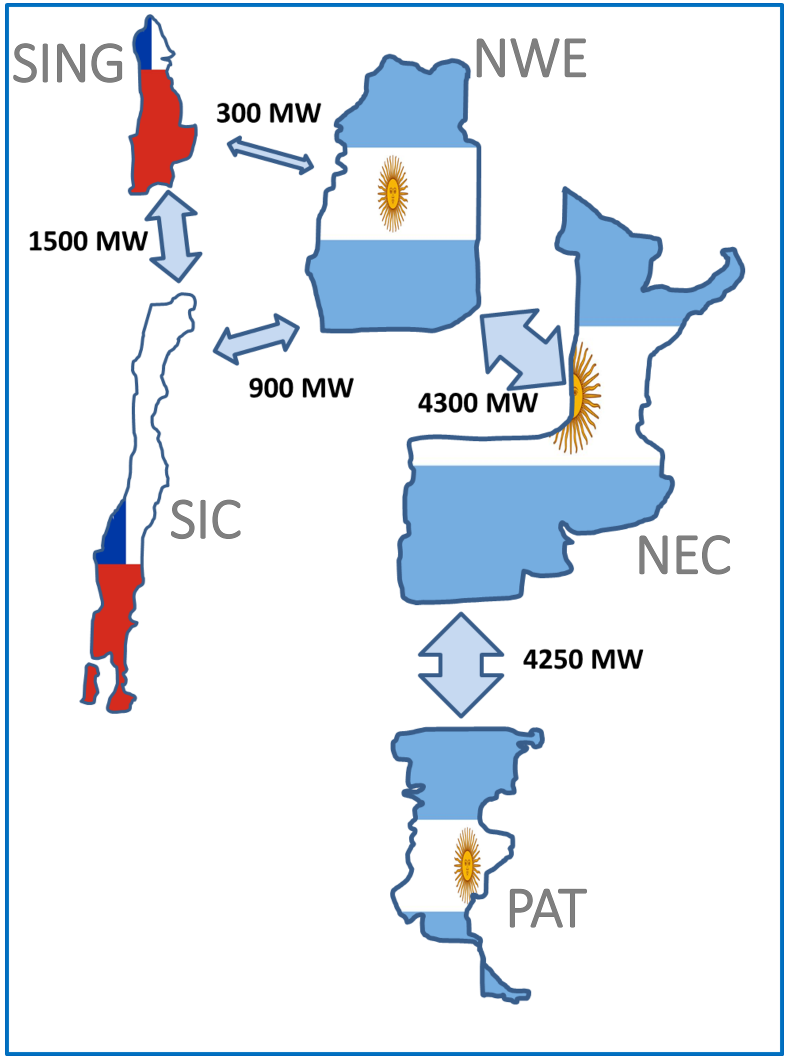
New interconnection between area of Santiago (CHI) and area of Gran Mendoza (ARG), 500 kV line with physical capacity up to 1,000 MW

new interconnection focus of the study

Electric power system model

Area model

- Macro areas model applied at each electric power system assuming inter-area limitation in transfer capacity
- Chile:
  - SING: Sistema Interconectado del Norte Grande
  - SIC: Sistema Interconectado Central
- Argentina:
  - NWE: North West area
  - NEC: North East and Central area
  - PAT: Patagonia area
- Net Transfer Capacity between the countries: 1,200 MW over a total physical capacity of 1,600 MW



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Methodology

- The expected operation of Chile-Argentina interconnected system were simulated by means of probabilistic simulations using GRARE (Grid Reliability and Adequacy Risk Evaluator) simulation tool (*)
- Probabilistic Monte Carlo method uses statistical sampling based on “Hybrid Non Sequential” approach (non-sequential analyses and optimization of thousands of weeks; sequential analysis and optimization of hydro generation over one year)
- Reserve requirements assessed taking into account the contingency reserve (loss of the biggest generation unit in service) with regulating and load following reserves. Regulating and load following reserves (non-event reserve) based on forecast error random drawings (demand forecast and VRES generation forecast)
- Wind and photovoltaic productions according to their stochastic behaviour based on expected average value, possible variability and typical patterns
- Impact of cross-border sharing of reserve and balancing resources on the total generation cost
  - Advantages of sharing reserve through the new interconnection

(*) Software developed by CESI on behalf of Terna (the Italian transmission system operator) - www.cesi.it/grare

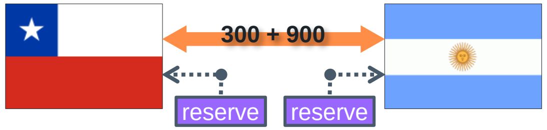
Methodology

The following scenarios have been analysed to evaluate the cost/benefit from operating reserve sharing between Chile and Argentina using the new interconnection line

NTC to energy exchange (MW)
NTC dedicated to reserve sharing (MW)

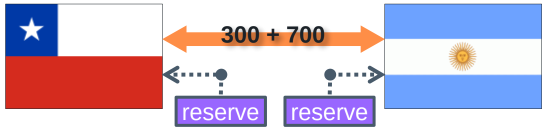
Scenario 1 (reference case)

- full NTC dedicated to energy exchange
- no reserve sharing



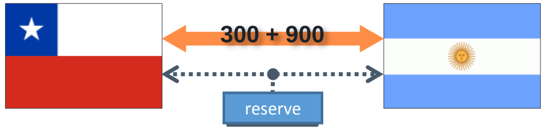
Scenario 2 (cost of reduced NTC)

- reduced NTC dedicated to energy exchange
- no reserve sharing



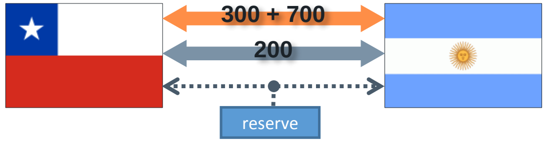
Scenario 3
(benefits form mutual support)

- full NTC dedicated to energy exchange
- operating reserve sharing



Scenario 4 (final case)

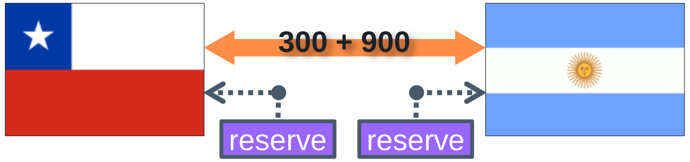
- reduced NTC dedicated to energy exchange
- operating reserve sharing considering dedicated interconnection capacity



Methodology

Scenario 1 (reference case)

- full NTC dedicated to energy exchange
- no reserve sharing

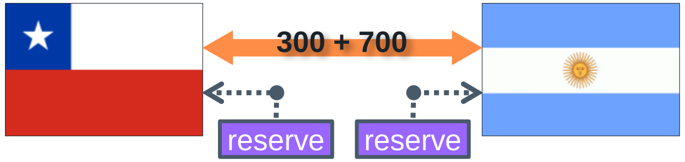


- Analysis of the overall system costs assuming that the reserve needed in each country is supplied by generators distributed in the different areas of that country
- Interconnections are used to transfer energy from a country with a lower production cost to a country with higher production cost to obtain the maximum benefit in terms of generation cost reduction
- This condition represents the reference case, in which the interconnection line could be exploited at its maximum possibilities to minimize system costs in terms of fuel costs and expected energy not supplied. The resulting values are taken as reference for the gap analysis with the results of the next scenarios

Methodology

Scenario 2 (cost of reduced NTC)

- reduced NTC dedicated to energy exchange
- no reserve sharing



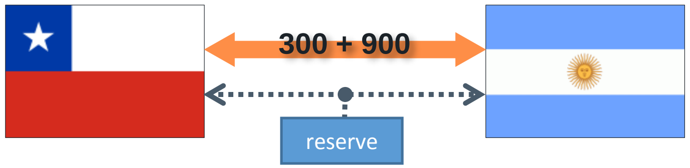
- The comparison with Scenario 1 provides the cost that the system has to face if a lower power exchange between countries is allowed. With reduced NTC dedicated only to the energy exchange (NTC=700 MW) the overall system costs will be higher than the reference Scenario 1, due to a more binding exchange constraint between countries which causes a less economic dispatching
- Also EENS (Expected Energy Not Supplied) in the countries could be impacted by the reduced NTC, and its increase would represent an additional cost for the system. This cost is however not taken into account in the evaluation because the limitation of the power transmission is applied only to the economic dispatching, and it is assumed that the full NTC remains available for mutual support in case one country suffers lack of generation while the other has power available.

Methodology

Scenario 3

(benefits form mutual support)

- full NTC dedicated to energy exchange
- operating reserve sharing

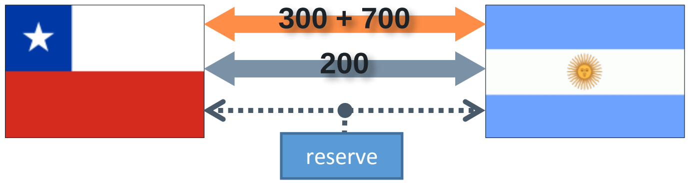


- Unlike Scenario 1, an agreement between Chile and Argentina is assumed to share the operating reserve, reducing the overall need for balancing sources and ancillary services. In this context, the reserve requirements of both countries are assumed to be non-simultaneous, therefore the reserve requirement of the whole interconnected system is the maximum value between those of the two countries
- The comparison with Scenario 1 provides the benefit that the interconnected system could obtain if a mutual support between countries is allowed and without a specific part of the interconnection capacity dedicated to balancing resource sharing
- The presence of the new stronger interconnection is essential to assume the agreement between the countries, as a weak interconnection based on a single line would not ensure enough security to allow one country to rely on the support of the other

Methodology

Scenario 4 (final case)

- reduced NTC dedicated to energy exchange
- operating reserve sharing considering dedicated interconnection capacity



- NTC of the new interconnection between Chile and Argentina is used as follow
  - 700MW dedicated to energy exchange for the economic dispatching of sources
  - 200MW dedicated to reserve sharing
- The comparison with Scenario 3 provides the benefit/cost that the interconnected system could obtain if part of the interconnection capacity is dedicated to balancing resource sharing instead of energy exchange in a context of cooperation between the countries
- 200MW of NTC dedicated to reserve sharing allows to use cheaper generation to meet system reserve requirements, reducing costs of balancing resources
- Different NTC values dedicated to reserve sharing have been assessed as sensitivity cases

Software tool

State of the art tool to assess system adequacy of large interconnected systems, simulating expected operating conditions (load variation, generation fleet, HV transmission system…) using probabilistic analysis:

- Probabilistic Monte Carlo method: statistical sampling based on a “hybrid sequential” approach
- Area modelling for the composite transmission-generation system
- Transmission network detail to represent each single area
- Generation fleet dispatched to minimise system costs
- Renewable aleatory production is obtained with a random drawing starting from real producibility figures
- Reserve level evaluation considering: biggest generating unit, uncertainty on load and VRES, possible aggregation of areas, fixed % of load

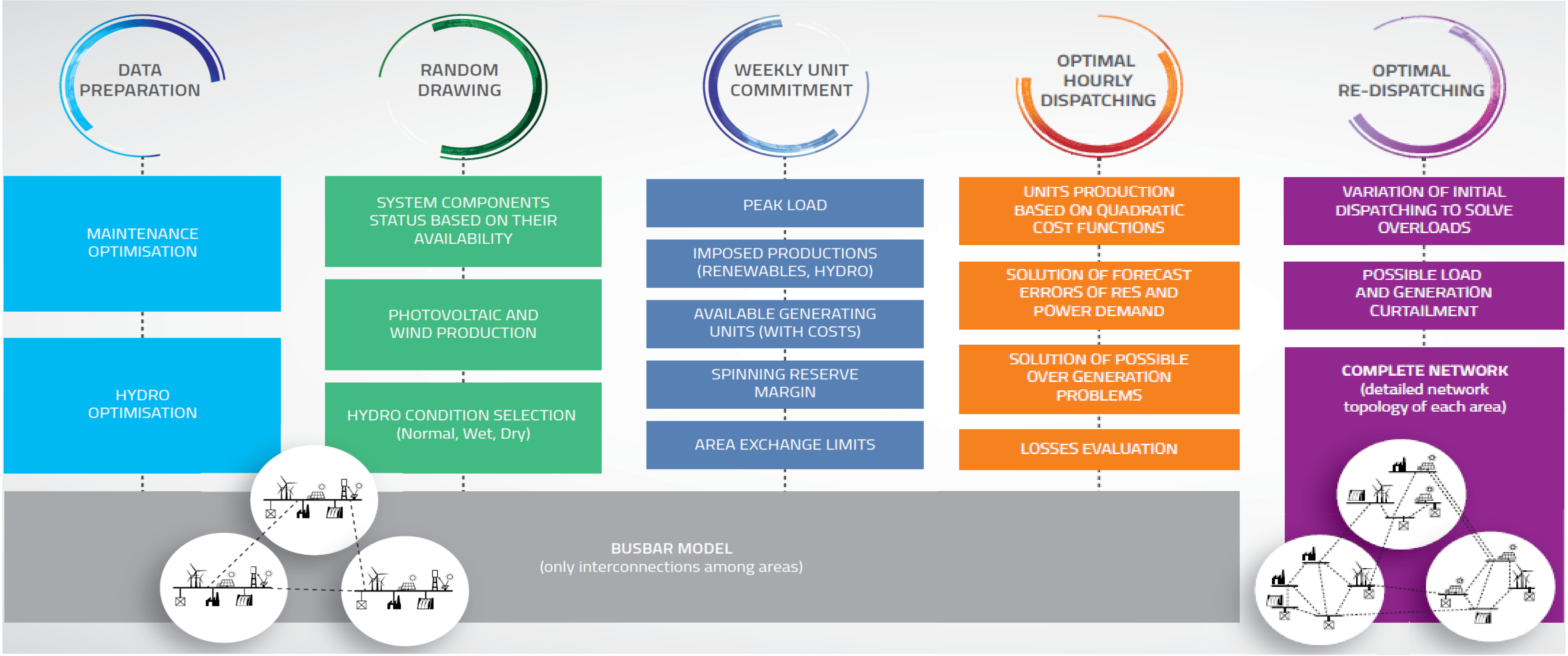
More details available on www.cesi.it/grare

GRARE
GRID RELIABILITY AND ADEQUACY RISK EVALUATOR

GRARE calculation process

The calculation process is performed as a series of sequential steps starting from a high-level system representation and drilling down to low-level network details:

(More details available on www.cesi.it/grare)



Main features of probabilistic simulations

- 200 Monte Carlo Years (MCY) have been simulated for the horizon year 2030:
  - A Monte Carlo Year (MCY) is a simulation year in which a mix of Monte Carlo variables is applied to take into account the stochastic behaviour of some power system parameters: load forecast error, forced outage rate of generation fleet and network elements, wind and solar generation
- Weekly optimization of power system operation minimizing system costs and unserved energy
- Thousands of system configurations, both with and without operating reserve sharing between Chile and Argentina
- Focus on the production cost of the whole interconnected system and benefits from reserve sharing using the new interconnection line between Chile and Argentina

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Results – Introduction

In the following slides the quantitative results of the analysis are presented. Focus is placed on

- the amount of energy produced by generators that are requested to stay in operation to fulfil the reserve requirement in each simulated condition, but that would not be selected according to a pure economic optimization because more than expensive which are the marginal unit (also identified as “reserve generators”)
- variation of fuel costs due to reserve requirement, which derives from the necessity to keep in operation generators which are more expensive than the marginal one in the optimal economic dispatch

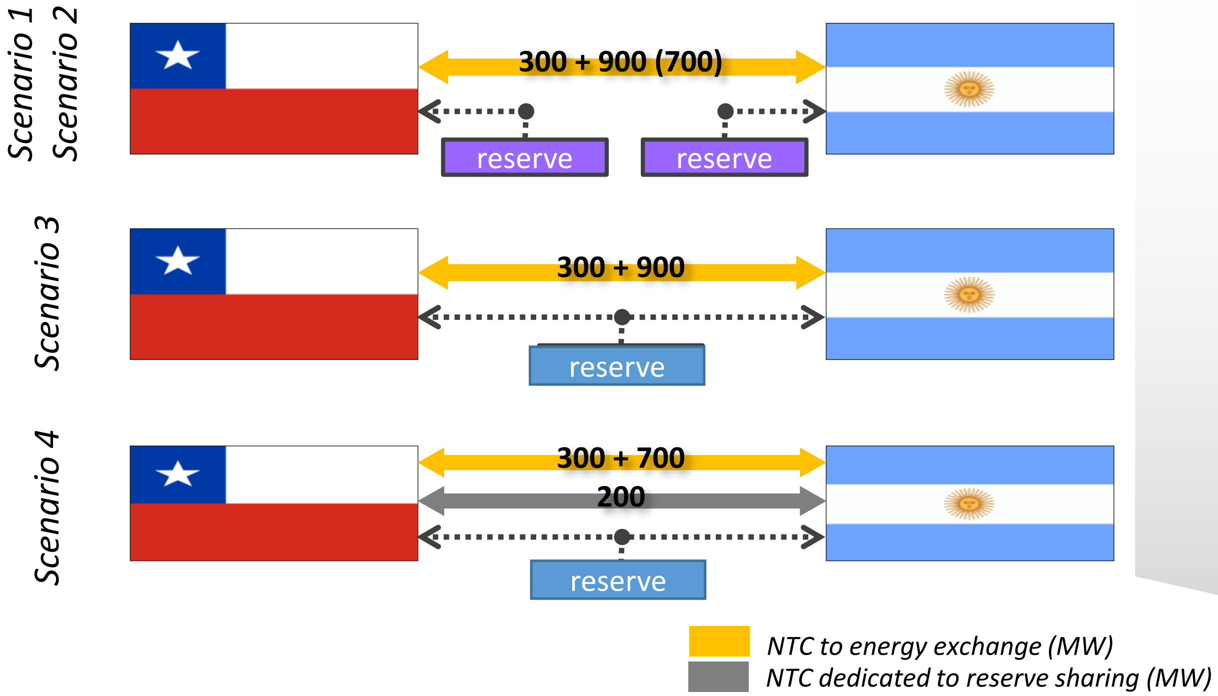
The different Scenario are compared in order to identify benefits and costs related to the sharing of reserve and limitation of NTC for energy exchange

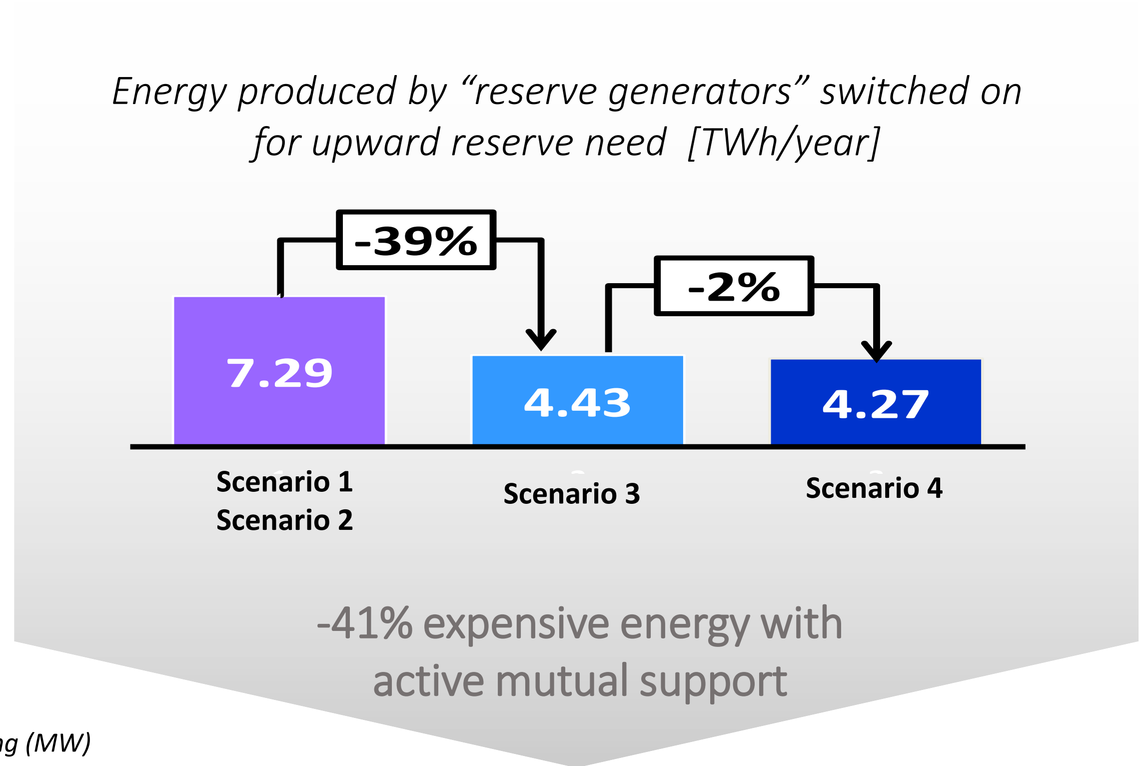
Operational costs are evaluated based on marginal costs of the generators, estimated taking into account different efficiencies and primary energy costs

Results – Reserve requirements

- Mutual support between countries allows an optimized use of resources to meet reserve requirements of each country. Lower reserve requirements imply a lower usage of "reserve generators", which must be switched on to provide upward reserve (energy reduced by 39-41% with active reserve sharing)

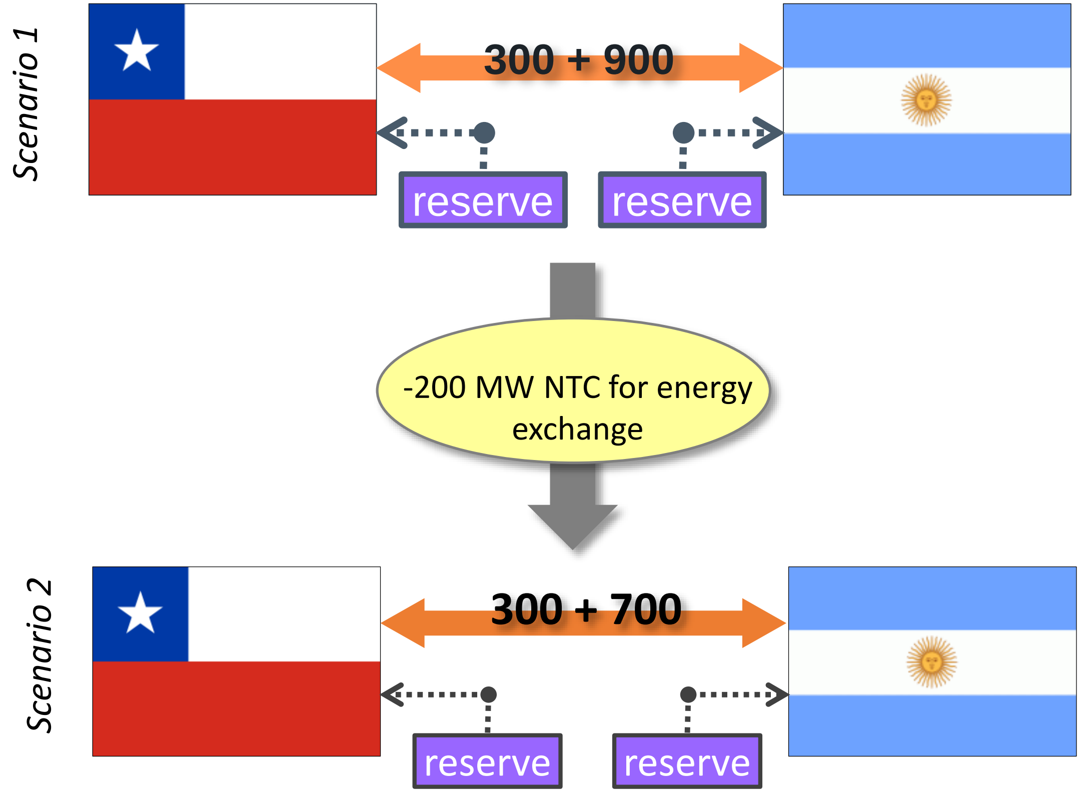
  A high level of system security is preserved





Results – System costs

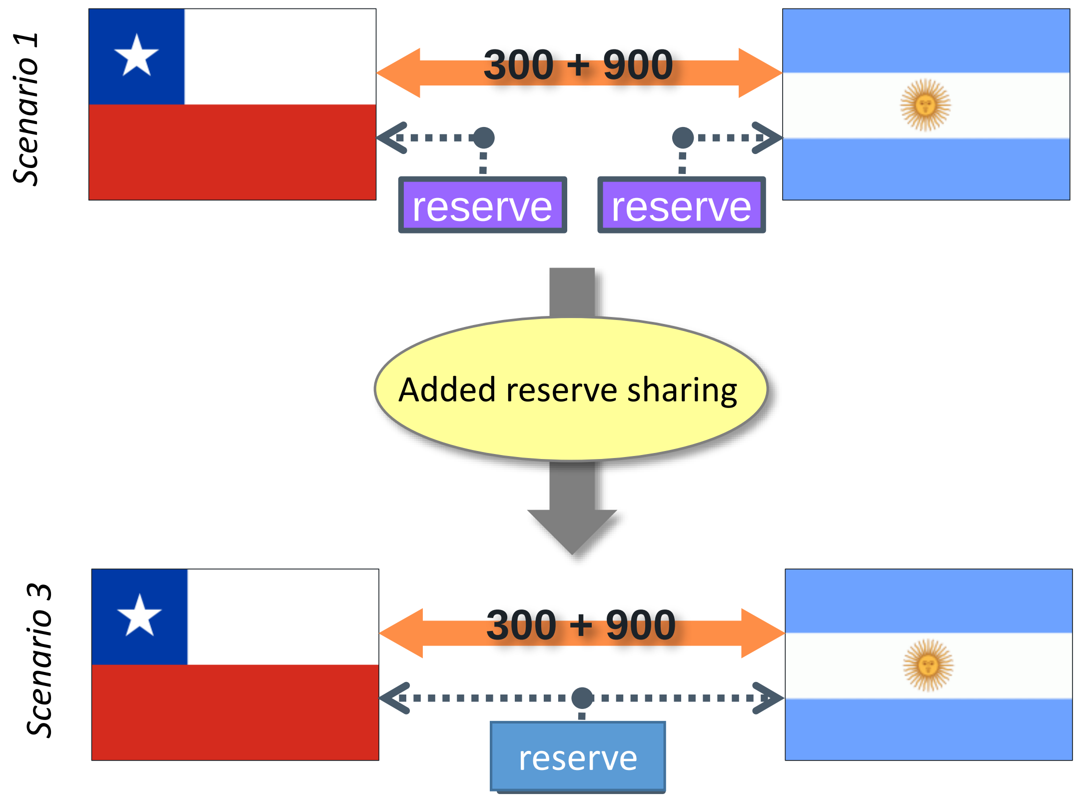
Impact of NTC reduction for energy exchanges



- Reducing NTC dedicated only to the energy exchange (NTC of the new interconnection equal to 700 MW), a less economic dispatching of generation resources occurs
- However, the extra cost for the whole system is limited:
  USD 1.7 million/year (+0.02% compared to total generation cost with full NTC)

Results – System costs

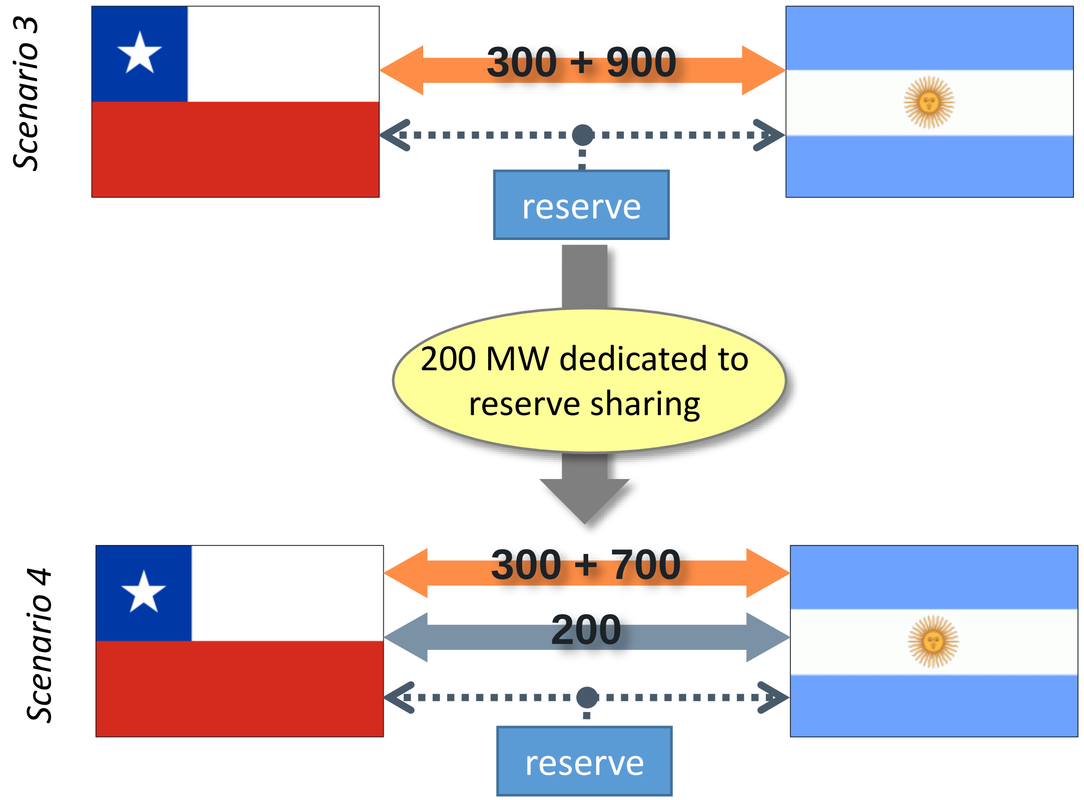
Impact of reserve sharing without dedicated NTC



- The sharing of balancing resources between countries allows a best economic use of generation sources preserving the security of the system
- The system could save USD 24.5 million/year (0.23% of system costs) only from the coordinated management of operating reserve, because of the lower need to switch on more expensive generators for reserve
- An accurate coordinated management of the operating reserve is crucial

Results – System costs

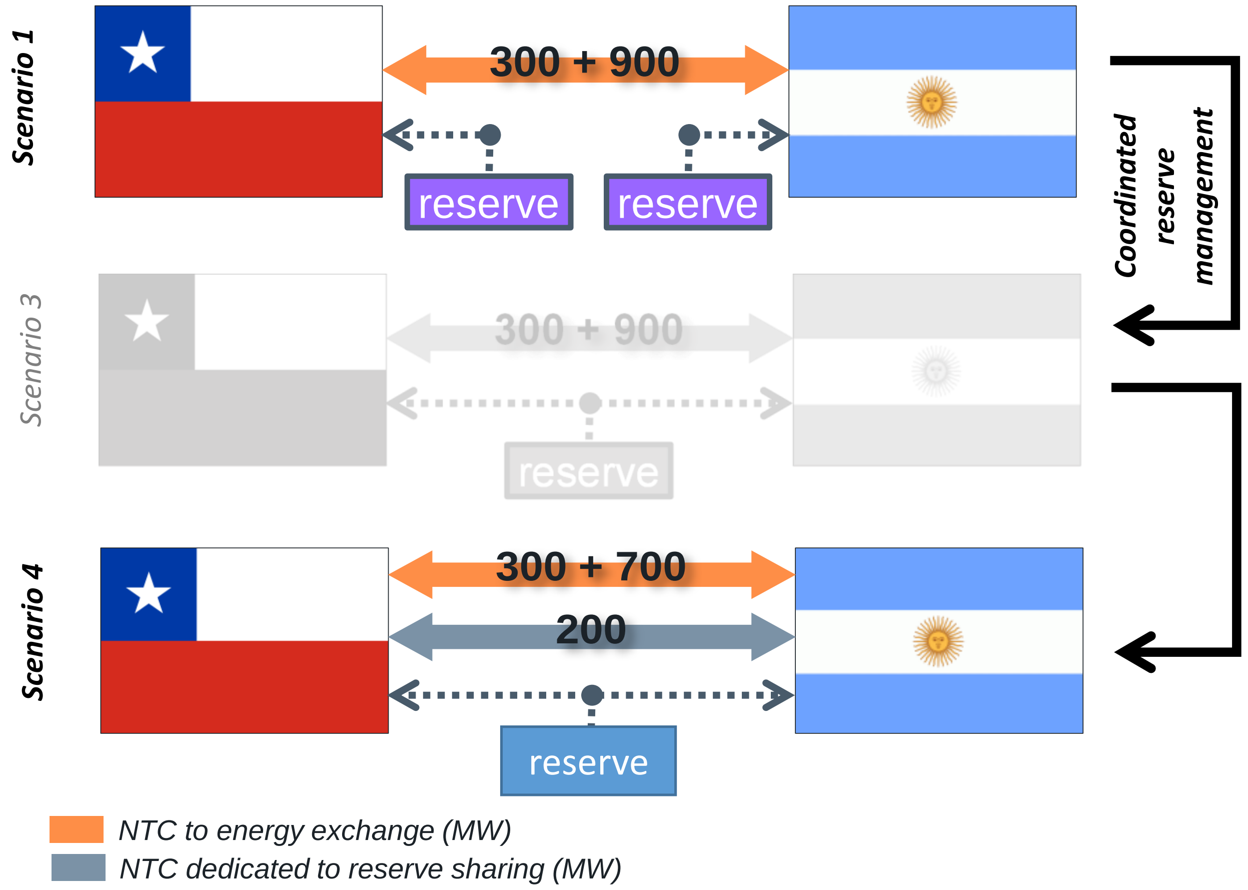
Impact of NTC dedicated to reserve sharing



- NTC dedicated to balancing resource sharing instead of energy exchange represents a net cost for the system as a consequence of
  - less economic dispatching (cost: USD 1.7 million)
  - lower costs for reserve (saving: USD 1.4 million)
- With 200 MW NTC dedicated to balancing resource sharing, the system would face additional costs for only USD 0.3 million/year with respect to Scenario 3

Results – System costs

Final result



The system can catch benefits from operating reserve sharing (in USD million)

+24.5 from coordinated reserve management

- 1.7 from reduced NTC for energy exchanges

+1.4 from better reserve sharing

+24.2 total saving (0.22% of fuel costs)

Results – Sensitivity analysis

Different values of NTC dedicated to reserve sharing have been checked

The increase of the costs (USD million) for the system is limited when the reserve is shared using the remaining interconnection capacity up to 900 MW with respect to the case fully dedicated to energy exchange

NTC energy exchange [MW]	NTC reserve sharing [MW]	Additional costs [USD million]	
		Without reserve sharing	With reserve sharing on remaining capacity
900	0	-	-
800	100	0.7	0.1
700	200	1.7	0.3
600	300	2.9	0.7
500	400	4.5	1.6

The reserve sharing limits the impact of reduced NTC on costs, because the full transmission capacity of the line is anyway exploited to optimize generation dispatch even without full energy exchange

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Conclusions

- The sharing of operating reserve brings advantages to the interconnected Argentina-Chile system. The mutual support between countries allows to use less generation resources during operation, reducing system costs (the energy produced by “reserve generators” needed to provide reserve but more expensive than optimal economic ones is reduced by 40%). Same system security is kept

- When part of the transmission capacity of the new interconnection between Chile and Argentina is assigned to the balancing resource sharing, two effects occur
  - more expensive dispatching of generation fleet to meet demand
  - cheaper cost of resources for balancing and ancillary services

- The combination of both effects results in an extra cost for the system, but for a negligible amount. The exploitation of the interconnection for most economic energy exchanges is convenient, but even when the transmission capacity is not used by energy flows, there might be benefits due to reduced reserve requirement and possible mutual support

Conclusions

- The generation fleets and the interconnection capacity between countries allow an adequate security of supply (low EENS). This level is maintained also with a coordinated management of balancing resources and with a NTC dedicated to the operating reserve sharing, which results in a benefit for the system, quantified in approximately 0.2% of the total generation costs

- No significant impact on a possible reduction of the installed capacity is expected because this value is related to the level of required security of supply (keeping EENS low especially in high load conditions, when all available generators are in service)

- Proper regulatory framework, agreements and operating procedures must be in place between the countries to allow that each one can rely on the resources available in the other enel

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