CIGRE RIAC

XVIII Encontro Regional Ibero-americano do CIGRE

Foz do Iguaçu - Paraná – Brasil, 19 a 23 de maio de 2019

XVIII eriac

Fórum das Nações
Update on Brazilian Electric Interconnections

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CIGRE
For power system expertise

May, 22th 2019

CIGRE Brasil

ITAIPU BINACIONAL

Update on Brazilian Electric Interconnections

Content

1 – INTRODUCTION

- South America Informative Data
  - Number of countries: 12
  - Population: about 423 millions inhabitants
  - Area: 17.740.000 km2
  - Gross Domestic Product (GDP per capta): U$/inhab = 14.687
  - Domestic Energy Supply (DES): about 590 million toe (Mtoe) equivalent to 4.3% of world

Update on Brazilian Electric Interconnections
2 – ABOUT SOUTH AMERICA ENERGY MATRIX

- Installed Capacity

Domestic Electricity Generation, by Country and Source - 2013 (%)

Country / Region	Coal	Oil	Natu-ral Gas	Nu-clear	Hydro	Others (*)	Total	Total (TWh)	% Rene-wables	% Fós-sils
Argentina	3	15	53	4	23	2	100	140	25	71
Bolivia	0	2	66	0	29	3	100	8	32	68
Brasil	3	4	12	3	69	10	100	570	79	19
Chile	42	8	16	0	27	8	100	75	34	66
Colombia	8	1	22	0	66	3	100	66	70	30
Equador	0	39	13	0	47	1	100	24	48	52
Guiana	0	95	0	0	0	5	100	2	5	95
Paraguai	0	0	0	0	100	0	100	59	100	0
Peru	2	4	44	0	49	2	100	42	51	49
Suriname	0	45	0	0	55	0	100	5	55	45
Uruguai	0	37	0	0	52	11	100	11	63	37
Venezuela	0	16	20	0	64	0	100	132	64	36
Total AS	5	8	20	2	59	6	100	1,135	66	33

(*) Included biomass and non-renewable industrial gases.

- Total generation power capacity in South America: 1.135 TWH
- Argentina 53% natural gás, Bolivia 66%, Peru 44%
- Brazil 69% hydro, Colombia 66%, Paraguay 100%, Peru 49%, Uruguay 52%, Venezuela 64%
- Chile 42% coal
- Ecuador: 49% oil, Guiana 95%, Uruguay 37%

CO_2 Emission per Country

Countries	CO_2 Emissi-ons (Mt)	GDP (PPP)/ pop. (US$/ capita)	DES/ pop (toe/ capita)	DES/ GDP (toe/ kUS$)	DES/ GDP (PPP) (toe/ kUS$)	Elec. cons./ pop (kWh/ capita)	CO_2/ DES (t CO_2/ toe)
Argentina	188.2	21,208	1.99	0.135	0.094	3,126	2.28
Bolivia	19.1	5,934	0.85	0.295	0.143	663	2.12
Brazil	460.7	14,444	1.47	0.132	0.102	2,557	1.56
Chile	82.0	21,714	2.17	0.138	0.100	3,912	2.14
Colombia	70.9	11,977	0.68	0.087	0.057	1,192	2.14
Ecuador	37.3	10,135	0.96	0.167	0.094	1,349	2.48
Guyana	1.9	6,342	1.18	0.307	0.186	902	1.98
Paraguay	5.6	7,787	0.78	0.178	0.101	1,344	1.05
Peru	49.5	11,400	0.73	0.110	0.064	1,246	2.23
Suriname	2.0	16,007	1.83	0.175	0.115	2,582	2.09
Uruguay	8.6	18,966	1.41	0.086	0.075	3,067	1.78
Venezuela	185.8	17,615	2.63	0.183	0.150	3,574	2.32
Total SA	1111.5	14,687	1.44	0.135	0.098	2,375	1.89
World	32,609	13,872	1.91	0.182	0.138	2,990	2.40
% SA/World	3.4	105.9	75.6	74.2	71.4	79.4	78.8

- Great presence of renewable sources in the energy Matrix. CO_2 energy emissions in South America in terms of CO_2 /toe of energy is about 1.89 against 2.4 in the world

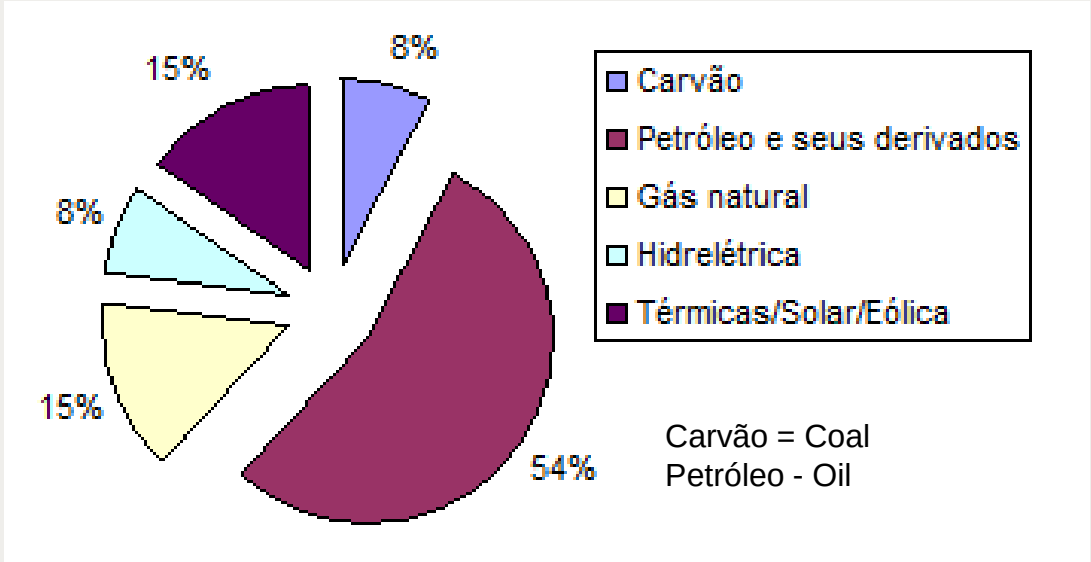
Source: M.M.E.

Update on Brazilian Electric Interconnections

2 – ABOUT SOUTH AMERICA ENERGY MATRIX

- **Energy Resources and Reserves**

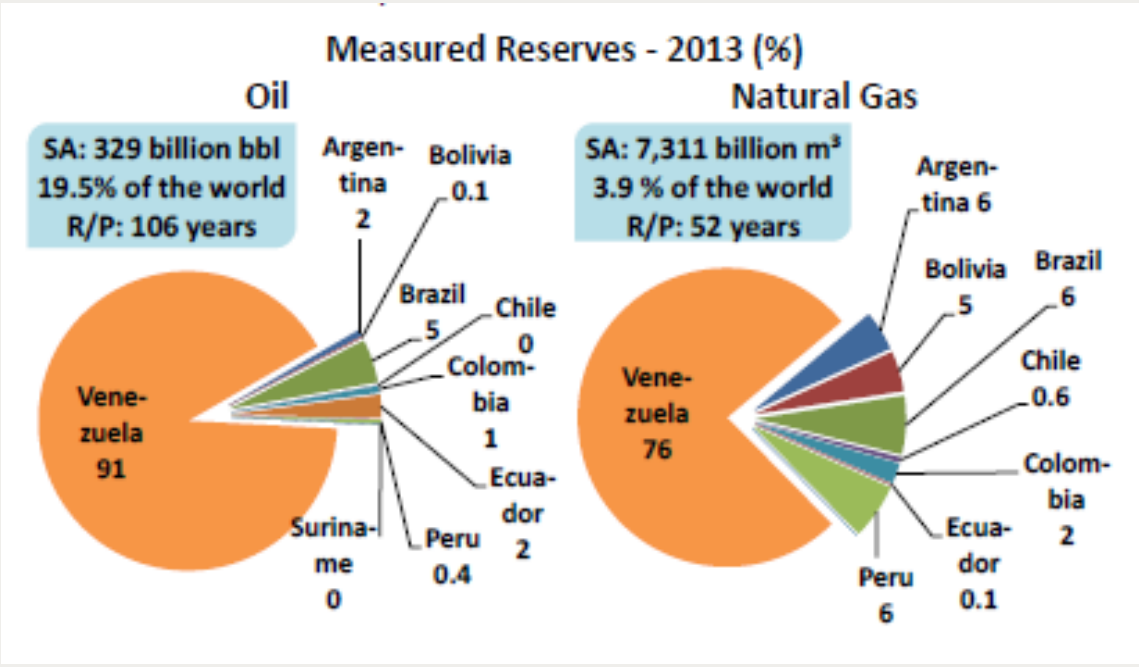
Latin America Energy Matrix



Carvão = Coal
Petróleo - Oil

Source: M.M.E.

Oil reserves in South America represent 19.5% of the world
Venezuela accounts for 91% of the regions reserves

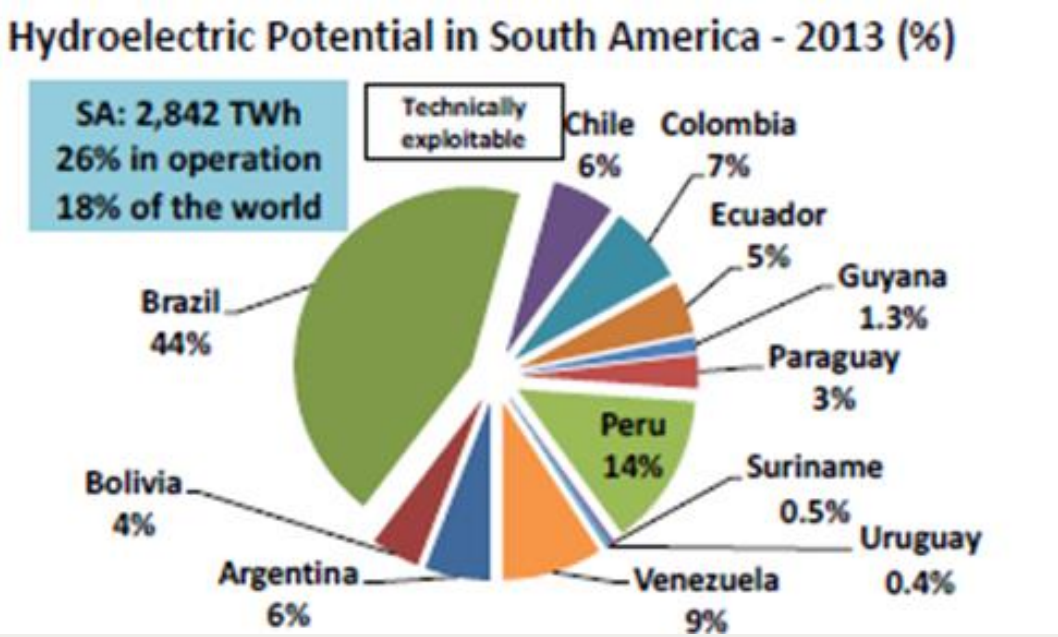


Oil and natural gas to export : Venezuela, Peru, Argentina, Bolivia

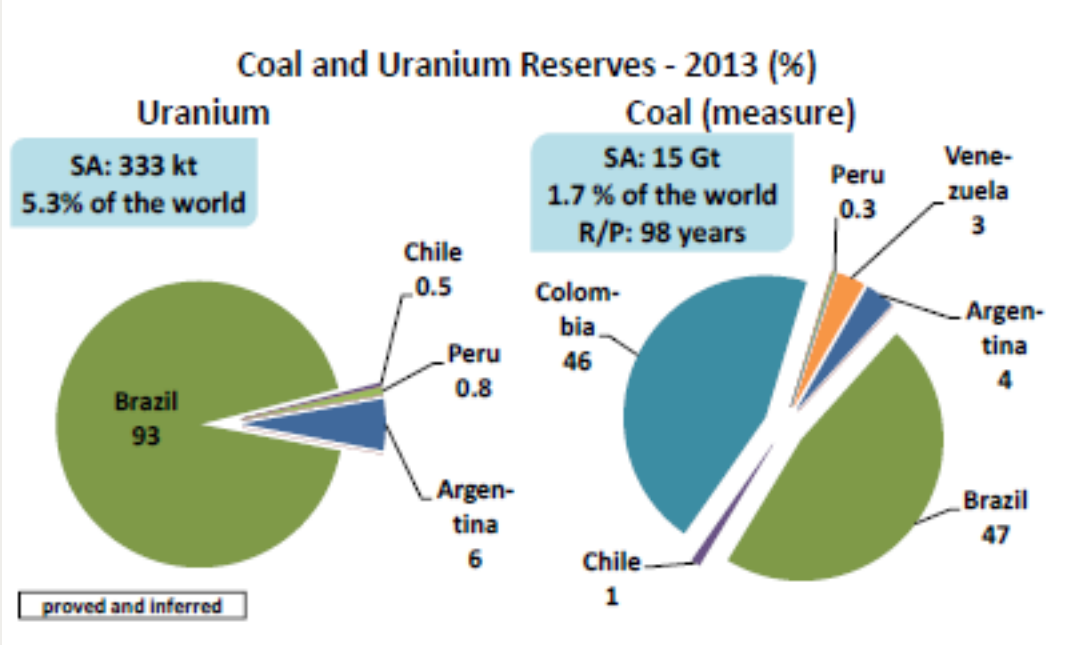
Update on Brazilian Electric Interconnections

2 – ABOUT SOUTH AMERICA ENERGY MATRIX

- **Energy Resources and Reserves**



Hydroelectric potential of South America: 2,842 TWh, 26% in operation, equivalent to 18% of the world's Hydroelectric energy: Brazil, Peru, Venezuela



Coal: Colombia
Uranium: Brazil, Argentina
Renewables wind & solar: Chile, Peru, Brazil, Argentina

Source: M.M.E.

Update on Brazilian Electric Interconnections

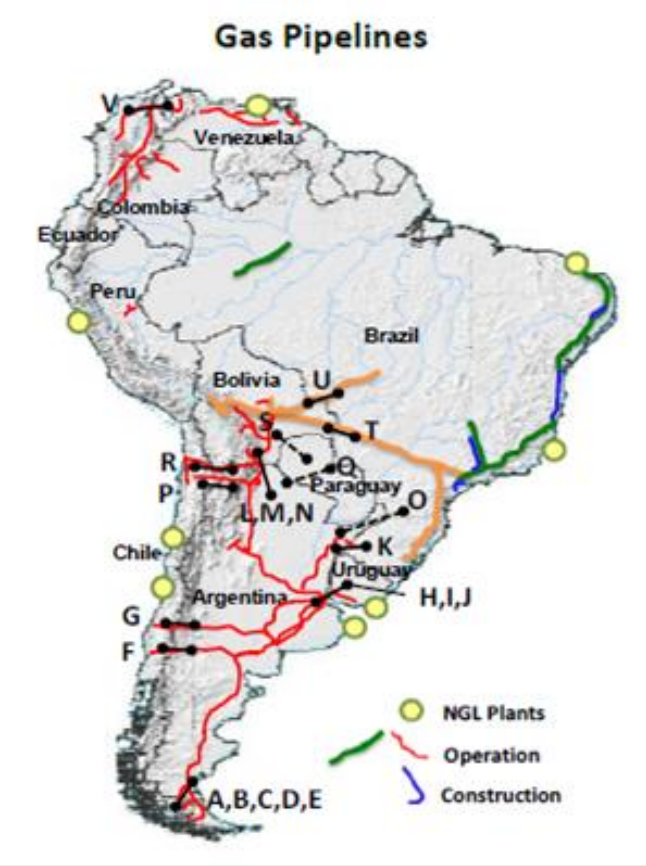
- Main characteristics:
  - A complete energy matrix
  - Well diversified and distributed
  - Strong existence of renewables

- Conclusions:
  - A complementary energy matrix: abundant and distributed resources
  - Great potential for energy exchange in the Region: mutual benefit for all
  - Key issue for region development

Update on Brazilian Electric Interconnections

3 – SOUTH AMERICA INTERCONNECTIONS

3.1 Oil & Gas Interconnections



Source: M.M.E.

Pipelines: Operation, Assembling and Study

Ref.	Coun-tries	Gas Pipelines	Dia-meter (Inch)	Capacity (Mm^3/d)	Situa-tion
A	AR - CL	San Sebastián (AR) - Pta. Arenas (CL) (Banduria)	10	4	Oper.
B	AR - CL	Bateria de Recepción 7 - T del Fuego	6	1.5	Oper.
C	AR - CL	Pta Dungeness (AR) - C. Negro (CL) (Dungeness)	8	2	Oper.
D	AR - CL	El Cóndor (AR) - Posesión (CL)	12	2.3	Oper.
E	AR - CL	Pta. Magallanes (AR) - Posesión (CL)	18	1	Oper.
F	AR - CL	L. La Lata (AR) - Concepción (CL) (Gas Pacífico)	24-20	3.5	Oper.
G	AR - CL	La Mora (AR) - Santiago (CL) (Gasandes)	24	10	Oper.
H	AR - UY	Gto. Entrerriano (AR) - Pay Sandú (UY) (Del Litoral)	10	1	Oper.
I	AR - UY	Gto. Entrerriano (AR) - Casa Blanca (UY)	16	5-2	Oper.
J	AR - UY	Bs. Aires (AR) - Montevideo (UY) (Cruz del Sur)	24	6	Oper.
K	AR - BR	Aldea Brasileira (AR) - Uruguayana (BR)	24	15-10	Oper.
L	AR - BO	Ramos (AR) - Bermejo (BO)	8-13	1.2	Oper.
M	AR - BO	Campo Durán (AR) - Madrejones (BO)	24	7	Oper.
N	AR - BO	Miraflores (AR) - Tupiza (BO) (Puna)	-	-	Proj.
O	AR - BR	Cnel. Cornejo (AR) - São Paulo (BR)	-	-	Proj.
P	AR - CL	Cnel. Cornejo (AR) - Mejillones (CL) (Casatacama)	20	9	Oper.
Q	AR - PY	Cnel. Cornejo (AR) - C. del Ester (PY)	-	-	stu.
R	AR - CL	Gasod. Norte (AR) - Tocopilla (CL) (Norandino)	20	8.5	Oper.
S	BO - PY	Vuelta Grande (BO) - Asunción (PY)	-	-	stu.
T	BO - BR	Rio Grande (BO) - S. Paulo (BR) (Gasbol)	32	30	Oper.
U	BO - BR	Rio Grande (BO) - Cuiabá (BR)	18	2.8	Oper.
V	CO - VE	Est. Ballena (CO) - Maracaibo (VE)	18	4.2	Oper.

- 22 projects
- 18 In operation

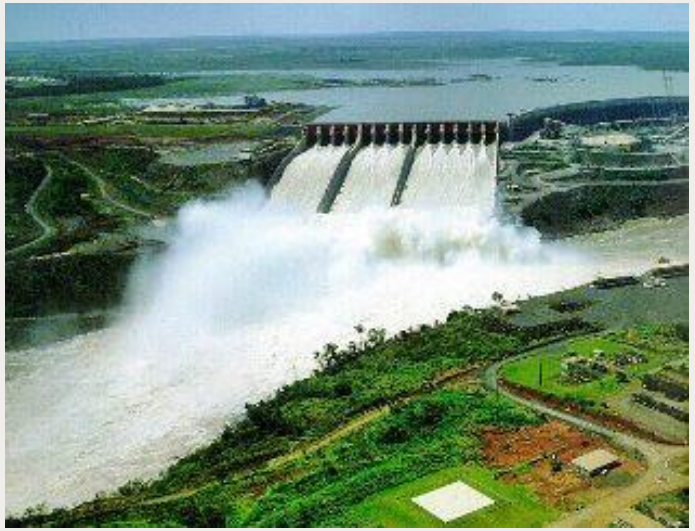
Update on Brazilian Electric Interconnections

3 – SOUTH AMERICA INTERCONNECTIONS

3.2 – Binational Hydropower Plants

Binational Hydropower Plants

Ref.	Countries	Name	River	Power	Situation
1	AR - UY	Salto Grande	Uruguay	1,890	Operation
2	AR - BR	Garabi	Uruguay	1,500	Study
3	AR - PY	Corpus	Paraná	3,400	Study
4	AR - PY	Yacyretá	Paraná	3,200	Operation
5	BR - PY	Itaipú	Paraná	14,000	Operation



Itaipu

Yacyretá

Update on Brazilian Electric Interconnections

3 – SOUTH AMERICA INTERCONNECTIONS

3.3 - Transmission Lines Interconnections

Source: M.M.E.

Transmission Lines: Operation, Construction and Study

Ref.	Countries	Name	Tension (kV)	Power (MW)	Situation
A	AR - UY	Salto Grande (AR) - Salto Grande (UY)	500	1,890	oper.
B	AR - UY	Concepción (AR) - Pay sandú (UY)	132-150	100	oper.
C	AR - UY	Colonia Elia (AR) - San Javier (UY)	500	1,386	oper.
D	BR - UY	P.te Médici (BR) - San Carlos (UY)	500	500	const.
E	BR - UY	Livramento (BR) - Rivera (UY)	230-150	70	oper.
F1	AR - BR	Rincón S.M. (AR) - Garabi (BR)	500	2,200	oper.
F2	AR - BR	-	-	2,120	stu.
G	AR - BR	P. de Los Livres (AR) - Uruguaiana (BR)	132-230	50	oper.
H	BR - PY	Saídas de Itaipu	750-220	14,000	oper.
I	BR - PY	Foz do Iguaçú (BR) - Acaray (PY)	230-138	50	oper.
J	AR - PY	Clorinda (AR) - Guarambaré	132-220	90	oper.
K	AR - PY	Saídas de Yacyretá	500	3,200	oper.
L	AR - PY	El Dorado (AR) - Mcal. A López (PY)	230-132	30	oper.
M	AR - CL	C.T.TermoAndes (AR) - Sub. Andes (CL)	345	633	oper.
N	BO - PE	La Paz (BO) - Puno (PE)	230-220	150	stu.
O	PE - BR	-	-	7,000	stu.
P	EC - PE	Machala (EC) - Zorritos (PE)	230	100	oper.
Q	CO - EC	Pasto (CO) - Quito (EC)	230	250	oper.
R	CO - EC	Jamondino (CO) - Santa Tosa (EC)	230	250	const.
S	CO - EC	Ipiales (CO) - Tulcán/Ibarra (EC)	115-138	113	oper.
T	BR - VE	Boa Vista (BR) - El Guri (VE)	230-400	200	oper.
U	CO - VE	Cuestecita (CO) - CuatricentenaRío (VE)	230	150	oper.
V	CO - VE	Tibú (CO) - La Fria (VE)	115	80	oper.
X	CO - VE	San Mateo (CO) - El Corozo (VE)	230	150	oper.
Z	CO - PA	Cerromatoso (CO) - Panamá (PA)	-	300	stu.
W	BR - GY	-	-	1,100	stu.

- 26 projects
- 19 In operation

Update on Brazilian Electric Interconnections

4 – BRAZILIAN EXISTING ELECTRIC INTERCONNECTIONS

Transmission Lines

Argentina & Brazil

- OHL 132 kV Uruguaiana / P. de los Libres: 50 MW (16.5kms)
- 2 x OHL 525 kV Rinco Sta Maria / Itá: 2100 MW (380 kms)

Uruguay & Brazil

- Riviera / S.Livramento Back-to-back SE: 70 MW
- OHL 525 kV Melo / Candiota: 500 MW (125 kms)

Paraguay & Brazil

- Itaipu Project (detailed later)

Venezuela & Brazil

- OHL 230 kV Sta Elena Uairén / Boa Vista: 200 MW (= 200 kms)

Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

5.1 – The Concept of Super Grids

- Here defined as an “important” or “strategic” or “large scale” electric interconnection”
  In this context could be:
- Very Long Distance Lines ≥ 1000 kms? HVDC?
- Ultra High Voltage OHL ≥ 500 kV?
- Big Power Carrying Capacity OHL ≥ 1000 MW?
- “Vital” Interconnections OHL: any voltage?
- Some “Super Grid” Challenges:
  - Low cost interconnections over large distances
  - Connecting asynchronous grid
  - Connecting remote energy resources and loads
  - Accommodating renewable electricity
  - Reliability / Unavailability

2 x 500 kV Tucuruí / Manaus

Update on Brazilian Electric Interconnections

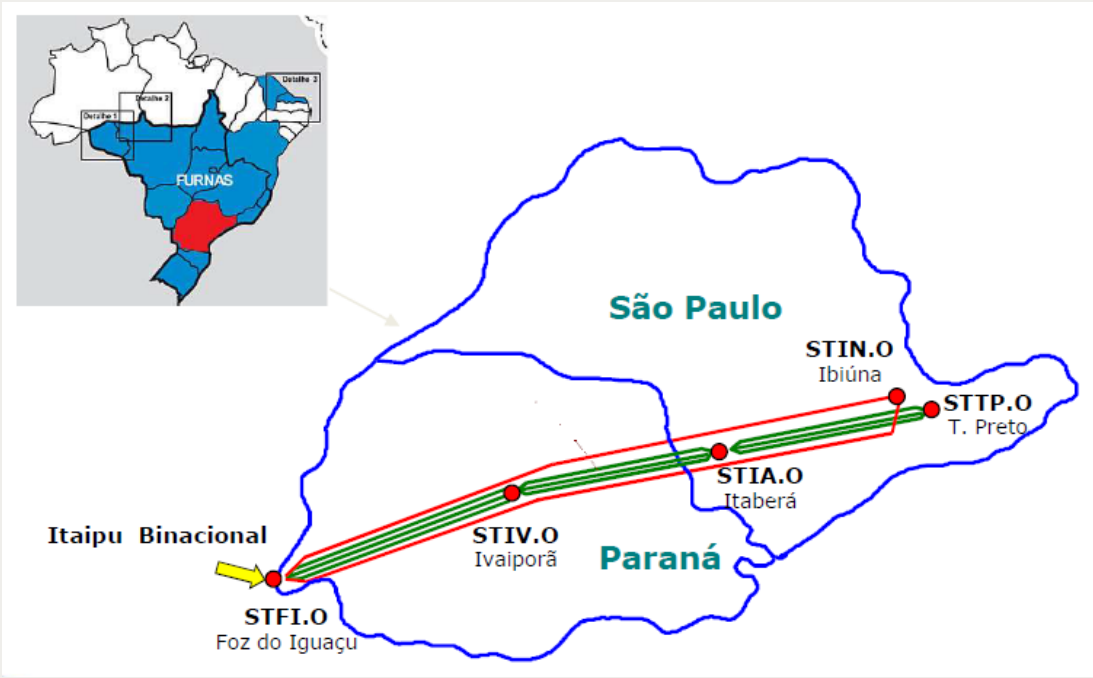
5 – BRAZILIAN “SUPER GRIDS”

- North & South Interconnections: 2 x 500 kV AC North / South (≅ 1200 kms)
- 2 x Teles Pires River 500 kV AC Transmission System (≅ 1900 kms)
- Tucuruí/Manaus 500 kV AC double circuit (≅ 1800 kms)
- Itaipu Transmission System (≅ 1000 kms)
- Madeira River UHVDC Transmission System (≅ 2400 kms)
- Belo Monte UHVDC Transmission System (≅ 2100 kms)

Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Itaipu UHV Transmission System



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5 – BRAZILIAN “SUPER GRIDS”

- Itaipu UHV Transmission System: Main Characteristics
  - 3 x 765 AC Foz de Iguaçu / T. Preto Transmission Lines ≅ 950 kms
  - 2 x +/- 600 kV DC Foz de Iguaçu / Ibiúna Bipoles ≅ 800 kms

Conductors:

- 765 kV AC Lines: 4 x ACSR Bluejay (1113 MCM)
- +/- 600 kV DC Lines: 4 x ACSR Bittern (1272 MCM)

Suspension Towers

- 765 kV AC Lines: V Guyed type
- +/- 600 kV DC Lines: Lattice monomastil guyed type

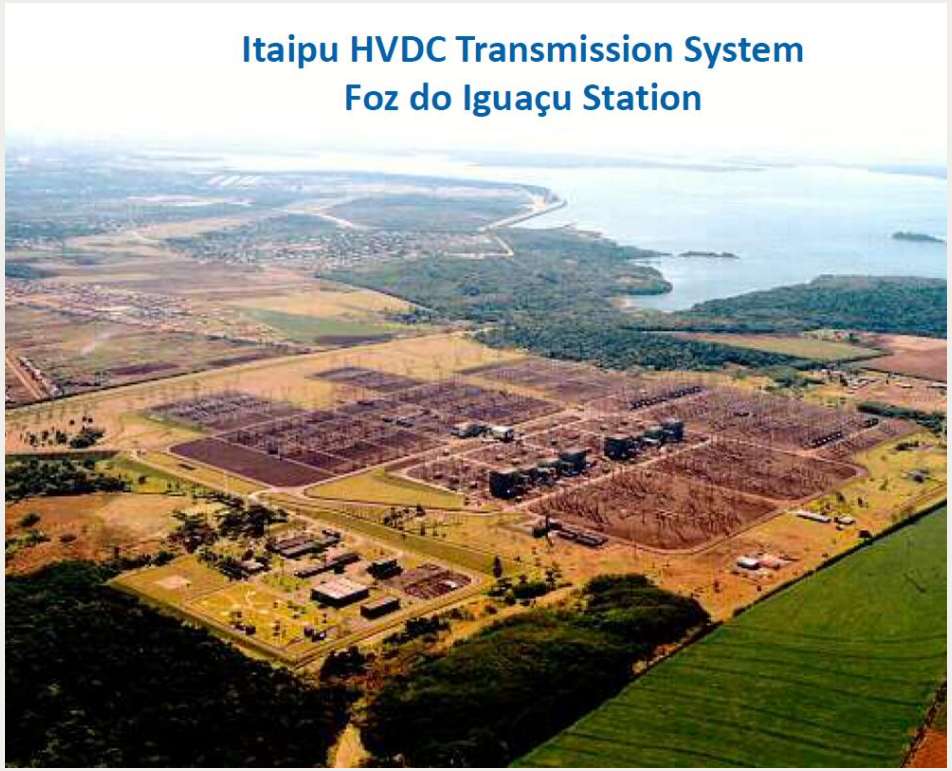
TL +/- 600 kV – Foz de Iguaçu – Ibiúna

TL 765 kV – Foz de Iguaçu – Tijuco Preto

Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Itaipu Transmission System: Substations



In operation since October 1985

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5 – BRAZILIAN “SUPER GRIDS”

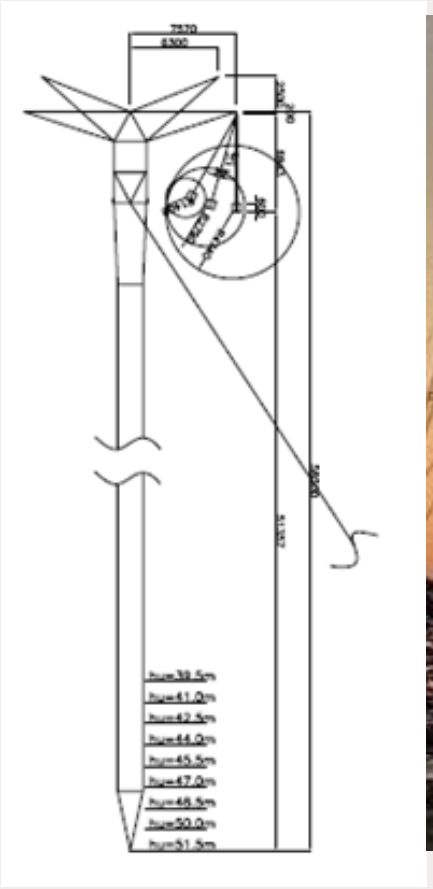
- Madeira River UHVDC Transmission System

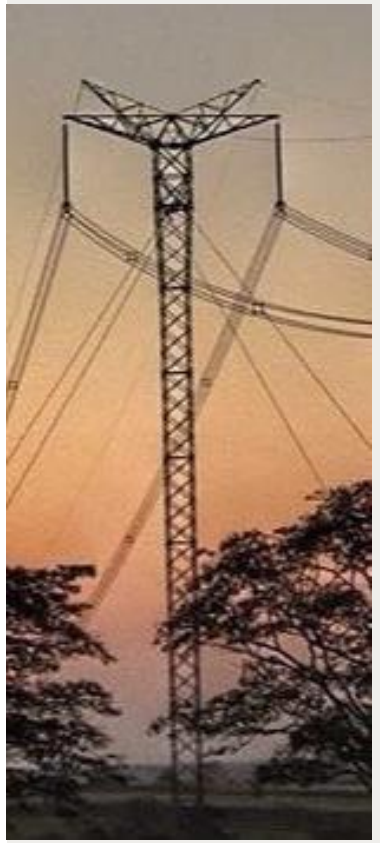
Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Madeira River UHVDC Transmission System: Main Characteristics

  - 2 +/- 600 kV Porto Velho / Araraquara DC Bipoles (= aprox. 2400 kms)
  - Conductors: 4 x AAC 2282.8 MCM conductors
  - Suspension towers: Lattice monomastil guyed type





Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Madeira River UHVDC Transmission System – Bipole 2: Substations

Porto Velho Substation

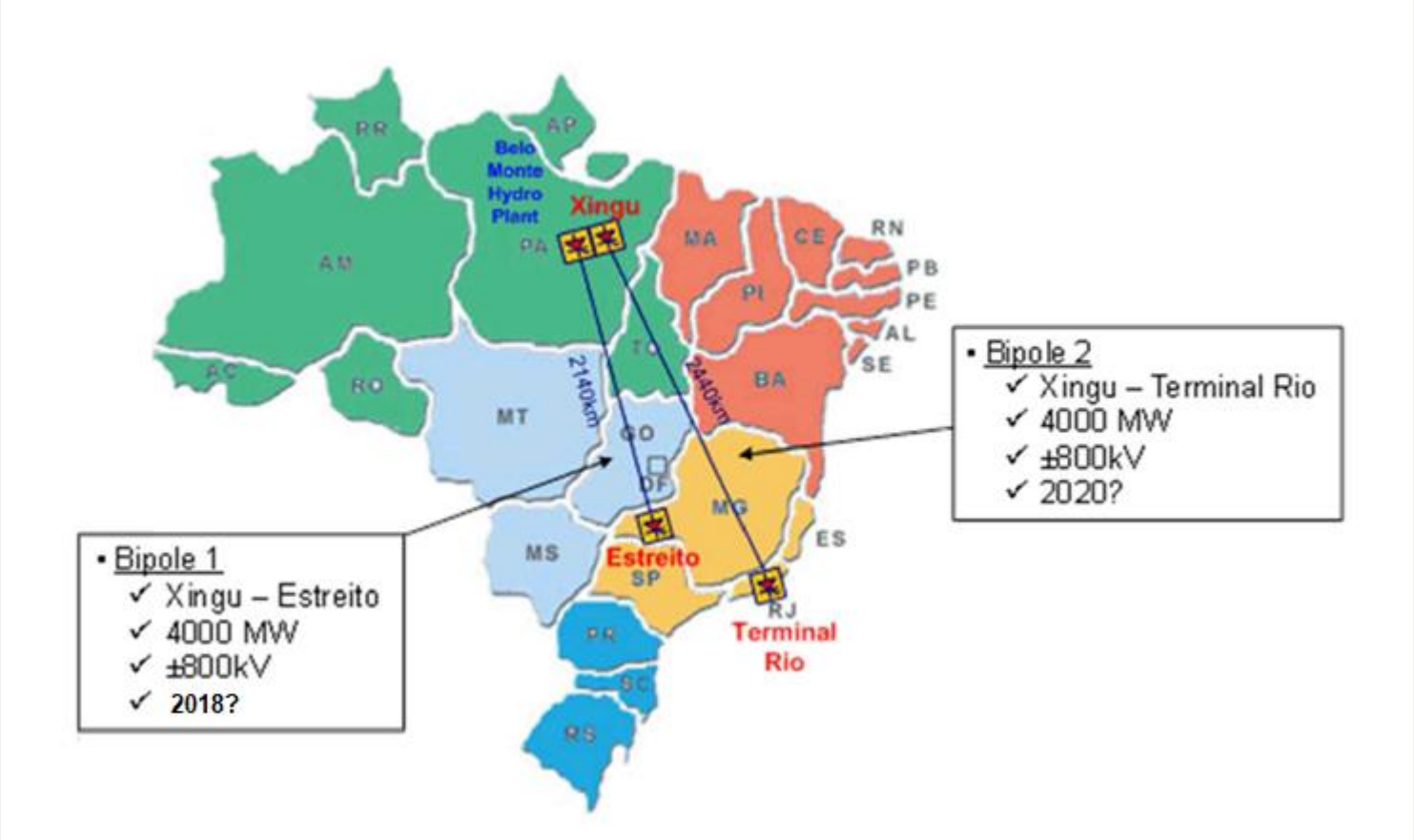
Araraquara 2 Substation

In operation since November 2013

Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Belo Monte UHVDC Transmission System

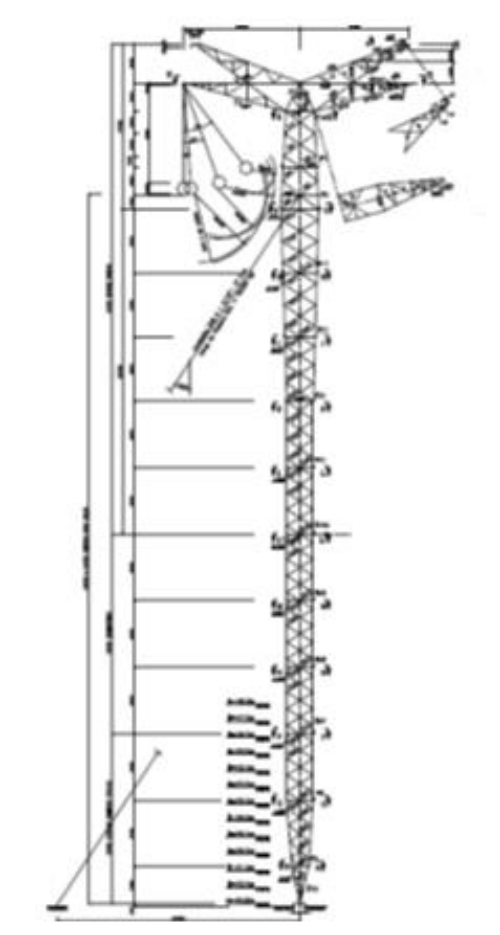


Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Belo Monte UHVDC Transmission System: Main Characteristics

  - +/- 800 kV DC Xingu / Estreito DC – Bipole 1
  - +/- 800 kV DC Xingu / N. Iguaçu – Bipole 2
  - Conductors: 6 x AAC 1590 MCM “Coreopsis” conductors
  - Suspension Tower: Lattice Monomastil Guyed Type



Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

- Belo Monte UHVDC Transmission System – Bipole 1: Substations

Xingu Substation

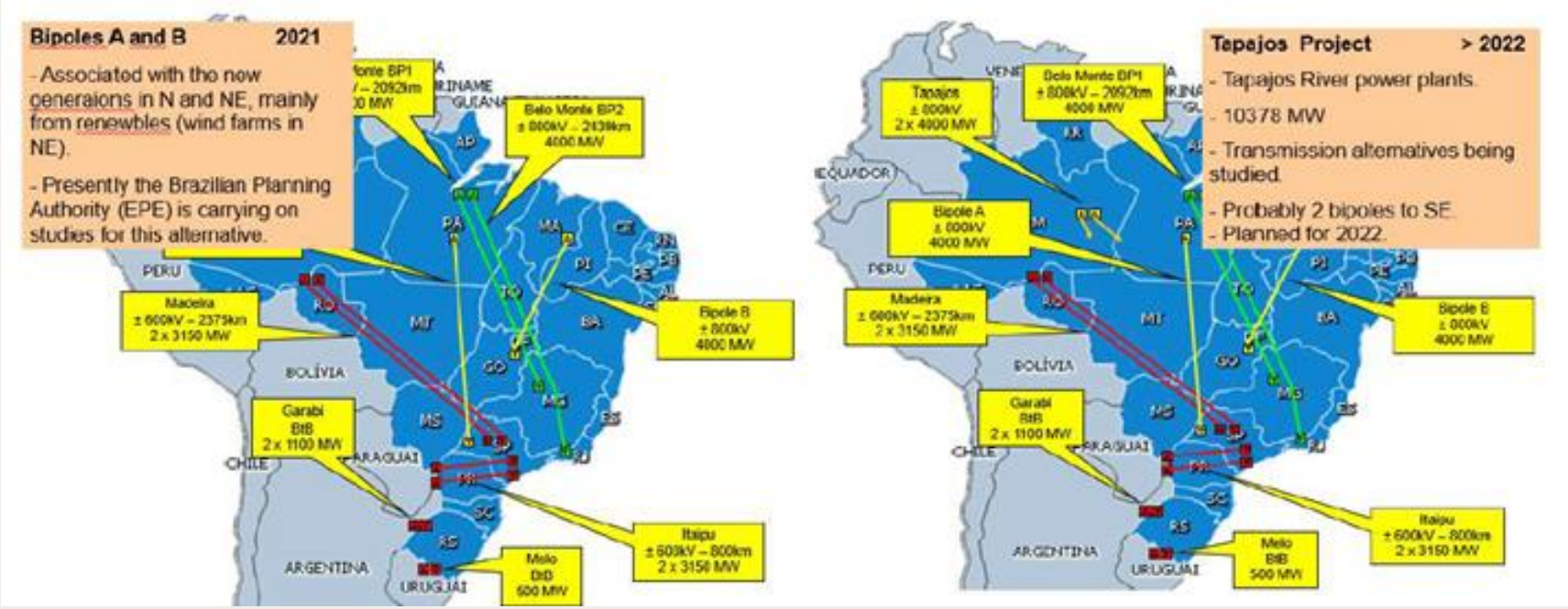
Estreito Substation

In operation since November 2017

Update on Brazilian Electric Interconnections

5 – BRAZILIAN “SUPER GRIDS”

New important UHVDC projects are coming…



6 – FUTURE INTERCONNECTIONS

Difficulties/Obstacles

- Environmental/land aspects: Environmental issues, land use (“Rain Forest”, natural reserves, Indigenous)
- Technical issues: Different frequencies, connecting asynchronous grids, etc
- Rules: Political discussions, market prices, local demands
- Financial resources: Own capital? Private/public partnerships? Project finance? Guarantees?
- Existing of grids: Pipe lines, transmission lines

Update on Brazilian Electric Interconnections
6 – FUTURE INTERCONNECTIONS

6.1 – Future Important Regional Projects

Argentina

+/- 500 kV DC OHL's: ≅ 2000 kms?
(Probably)

Patagonia Wind
Generation ≅ 5000 MW?

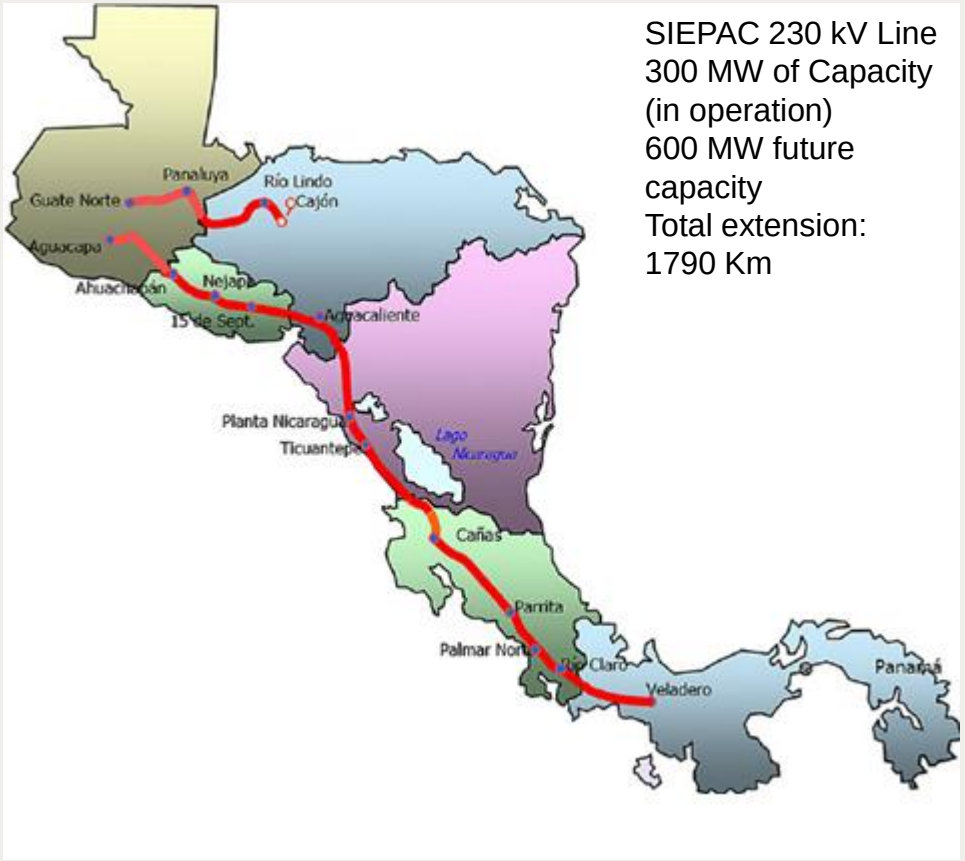
Chile

Atacama Solar & Wind
Generation ≅ 3000 MW?

+/- 600 kV DC OHL's:
≅ 1500 kms?

Update on Brazilian Electric Interconnections
6 – FUTURE INTERCONNECTIONS

6.1 – Future Important Regional Projects
SIEPAC – Central America Interconnection: Guatemala, El Salvador, Honduras, Nicarágua, Costa Rica, Panamá



SIEPAC 230 kV Line
300 MW of Capacity (in operation)
600 MW future capacity
Total extension: 1790 Km

Future

- Guatemala / Mexico Interconnection: 400 kV OHL ≅ 103 km
- Panama / Colombia: +/- 500 kV HVDC Panama II / Cerromatoso Interconnection?

Update on Brazilian Electric Interconnections

6 – FUTURE INTERCONNECTIONS

6.1 – Future Important Regional Projects
SINEA – Andean Interconnections Colombia, Ecuador, Peru, Bolivia, Chile

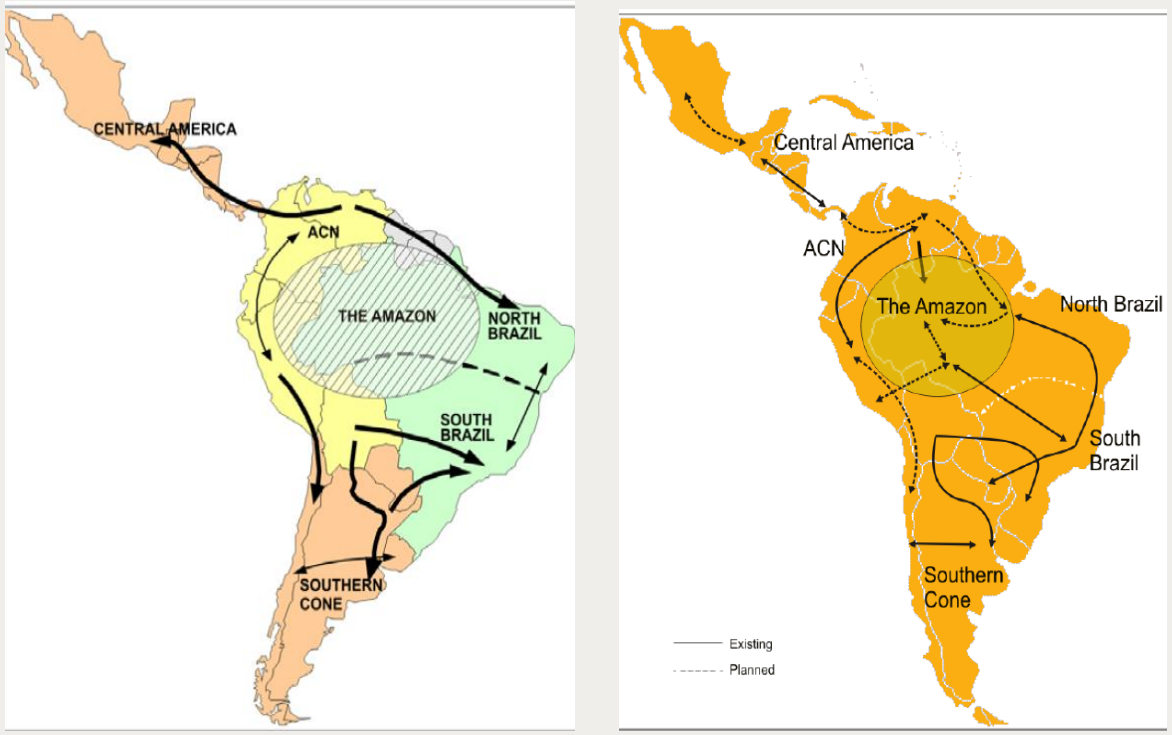
- Declaración de Lima: 2014
- Marco Regulatorio en preparación
- Creado “Consejo de Ministros del SINEA”: 29 y 30 Abril 2019

Update on Brazilian Electric Interconnections

6 – FUTURE INTERCONNECTIONS

6.2 – Future Brazilian International Interconnection:

- Reinforcement existing Argentina & Brazil (existing or new ones)
- Reinforcement existing Venezuela & Brazil (500 kV Manaus/Boa Vista in construction)
- Brazil & Paraguay & Argentina “Super Grid”: In study
- Peru & Brazil: In study
- Colombia & Brazil: To be studied/planned
- Bolivia & Brazil: To be studied/planned



Latin America Interconnections