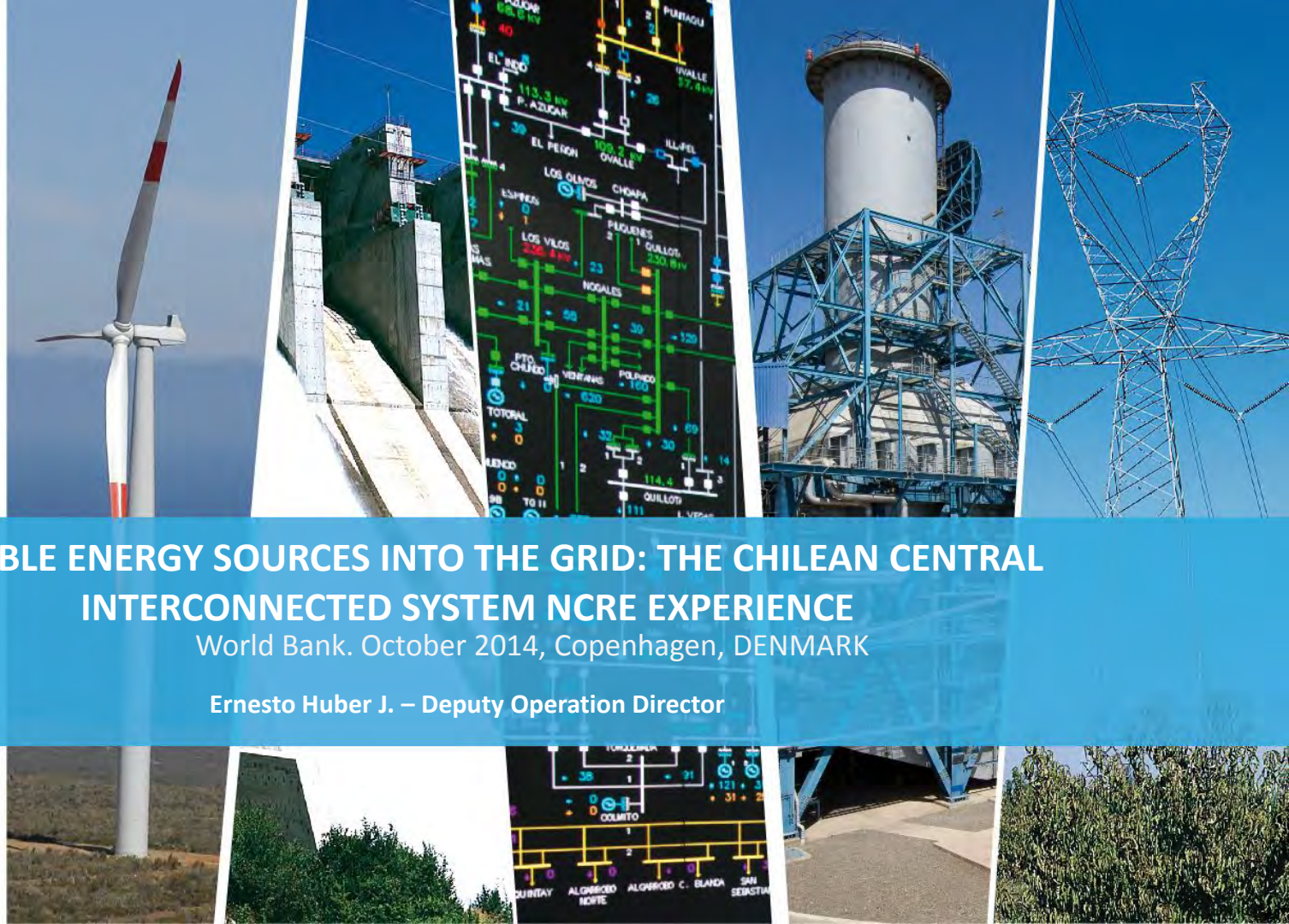
CDEC-SIC



VARIABLE ENERGY SOURCES INTO THE GRID: THE CHILEAN CENTRAL INTERCONNECTED SYSTEM NCRE EXPERIENCE

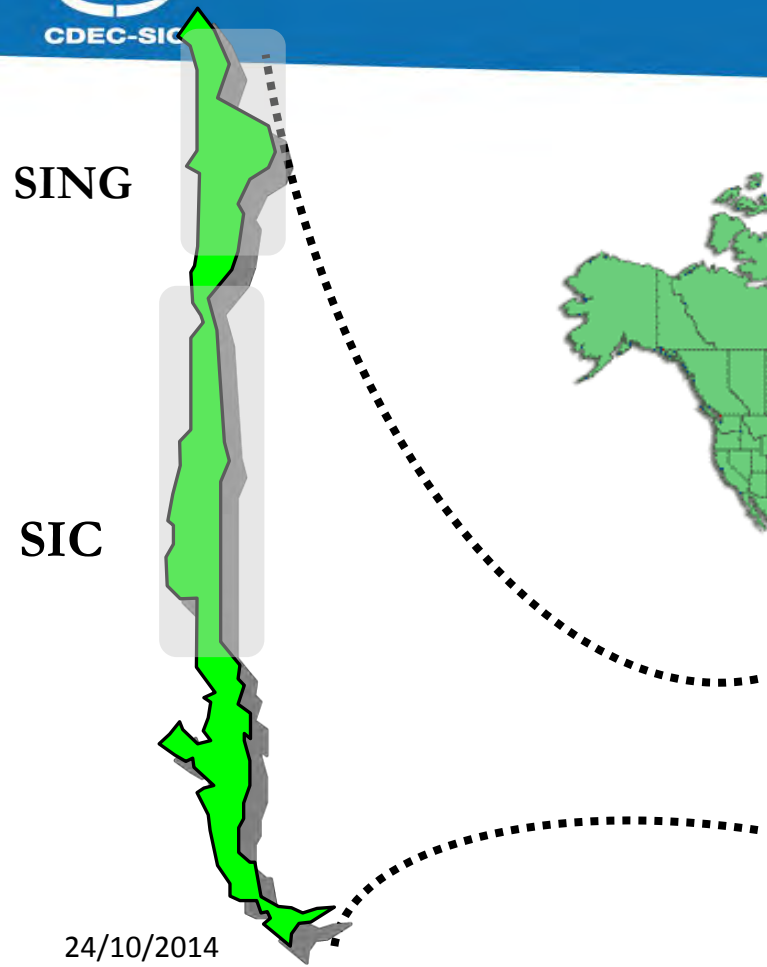
World Bank. October 2014, Copenhagen, DENMARK

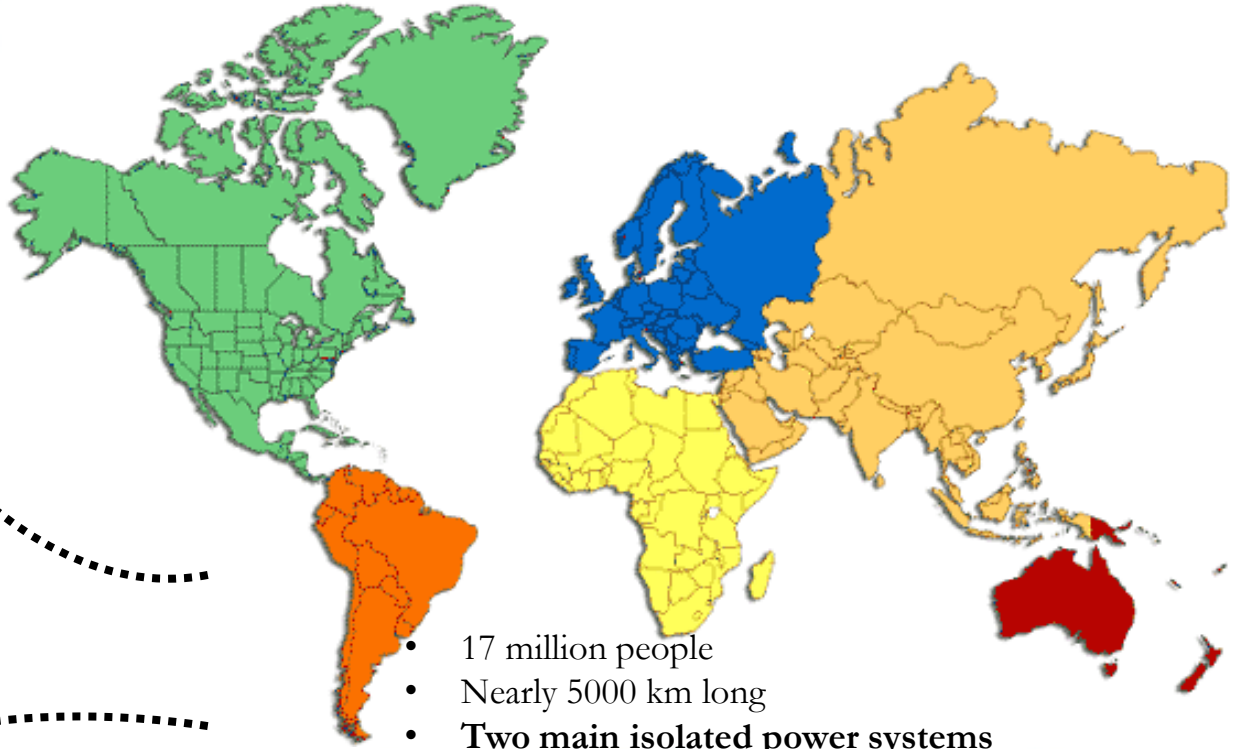
Ernesto Huber J. – Deputy Operation Director

AGENDA

1. GENERAL PRESENTATION.
   - CHILEAN ELECTRIC POWER SYSTEMS
   - INSTALLED CAPACITY AT THE CENTRAL INTERCONNECTED SYSTEM (SIC)
   - LOAD ECONOMIC DISPATCH CENTER AT SIC (CDEC-SIC): ISO-IMO
   - GENERATION AND ENERGY PRICES: HISTORICAL OVERVIEW
   - NCRE IN THE CHILEAN ELECTRICITY MARKET
2. THE NORTHERN PART OF THE SIC: CHARACTERISTICS
3. NCRE GRID IMPACT: AUTOMATIC SCHEME DESIGN FOR NORTHERN SIC
4. FINAL REMARKS.

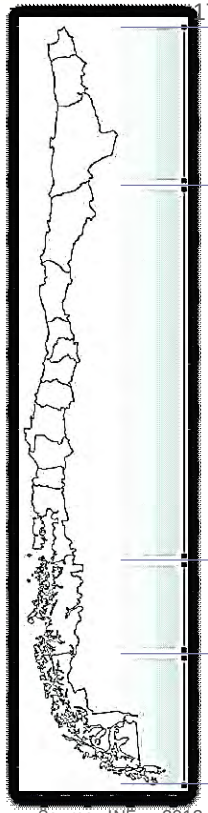
CHILE: MAIN FEATURES





- 17 million people
- Nearly 5000 km long
- **Two main isolated power systems**

CDEC-SIC



Population
17.4 millions

6.31%

92.16%

0.61%

0.92%

Source: INE - 2012

Northern Interconnected System (SING)

Installed Capacity MW	4,606	24.4%
Annual Generation GWh/y	17,237	25.1%
Peak Load MW	2,226	23.2%

Eastern Island Electric Power System
3.09 MW

Central Interconnected System (SIC)

Installed Capacity MW	14,080	74.7%
Annual Generation GWh/y	50,906	74.2%
Peak Load MW	7,282	76.0%

Lakes Zone Electric Power System
5.42 MW

Aysén´s System

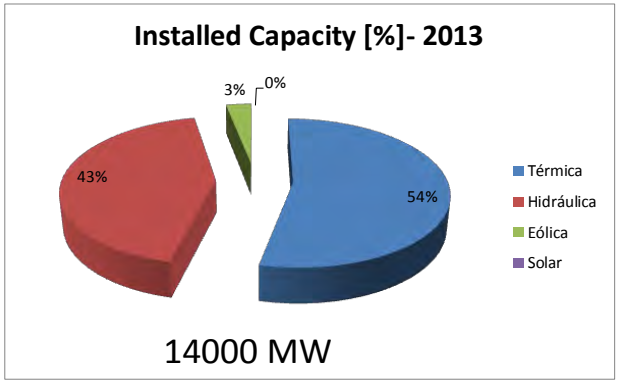
Installed Capacity MW	50.2	0.3%
Annual Generation GWh/y	154.6	0.2%
Peak Load MW	25.3	0.3%

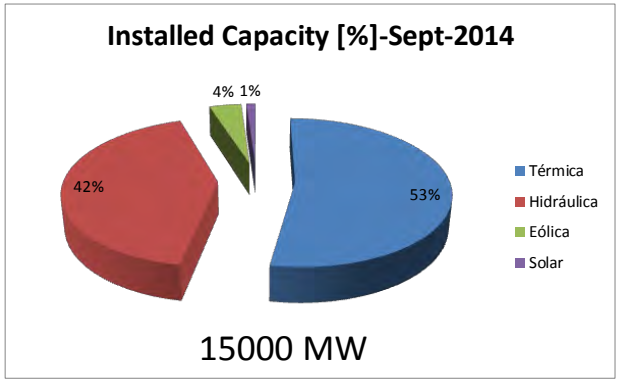
Magallanes´s System

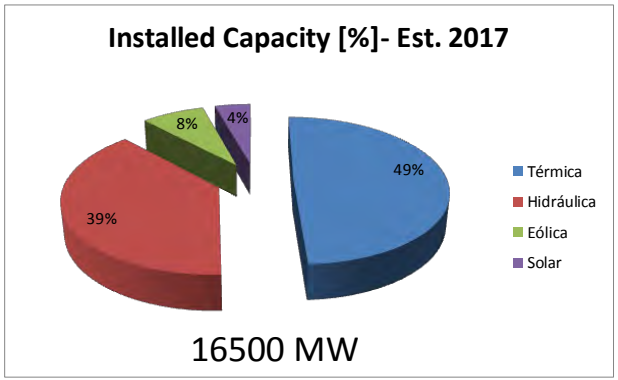
Installed Capacity MW	111.7	0.6%
Generación Anual GWh/año	290.6	0.4%
Demanda Máxima MW	51.7	0.5%

Source: CNE/CDEC-SING/CDEC-SIC - 2013

INSTALLED CAPACITY AT CENTRAL INTERCONNECTED POWER SYSTEM

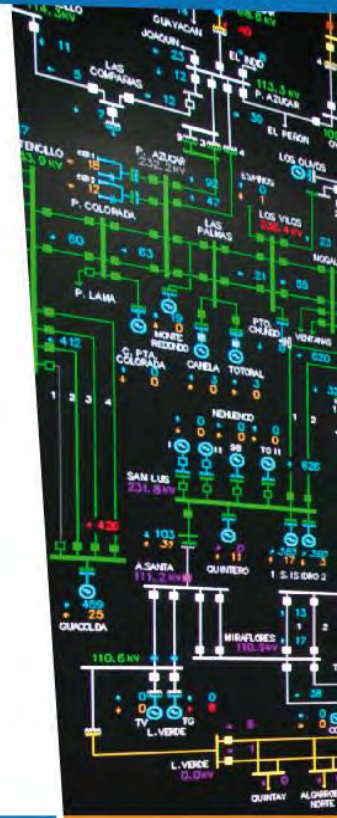




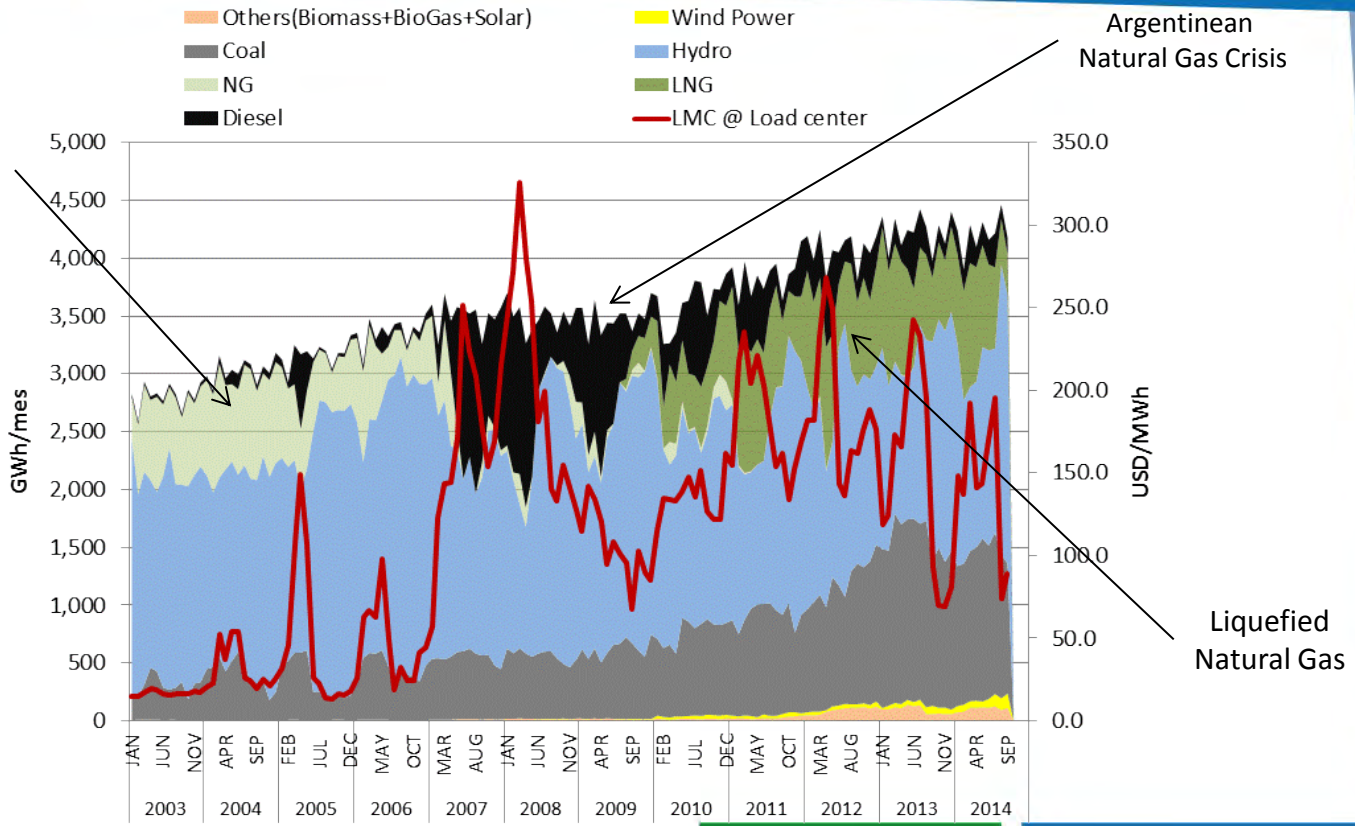


CDEC-SIC

- CDEC-SIC (SIC´s ISO) is an entity responsible for oversees the operation of SIC power system, including:
  - power plants;
  - transmission lines of the trunk, sub-transmission and additional systems;
  - electric substations, including the primary distribution substations, and
  - consumption bars of users that are not subject to price regulation and supplied directly from facilities of a transmission system
- **Each CDEC is responsible to coordinate the operation of the whole facilities in its electric power system, taking into account the following guide lines:**
  - **Preserve the service security in the electric grid;**
  - **Guarantee the most economic operation for all the facilities of the electric grid;**
  - **Guarantee open access to the main transmission and sub-transmission systems.**



GENERATION AND ENERGY PRICES: HISTORICAL EVOLUTION



First Natural Gas curtailment from Argentina

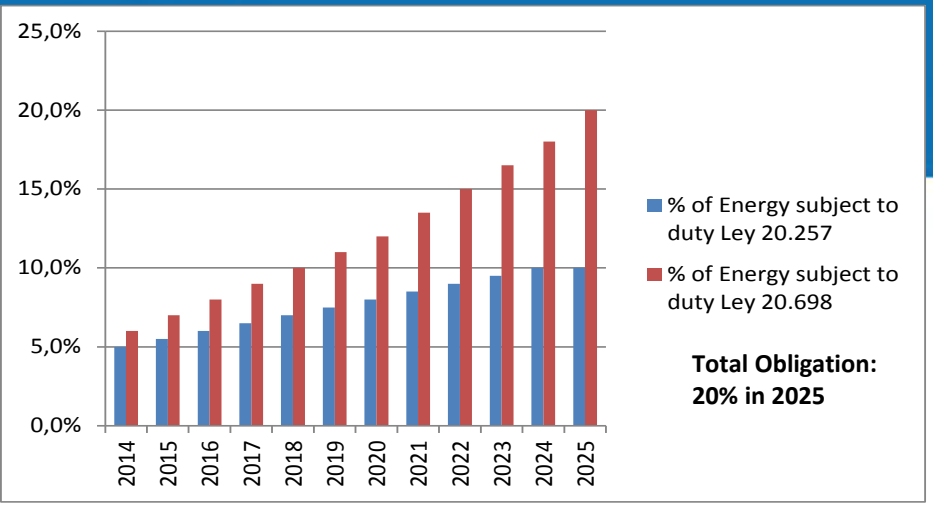
Argentinean Natural Gas Crisis

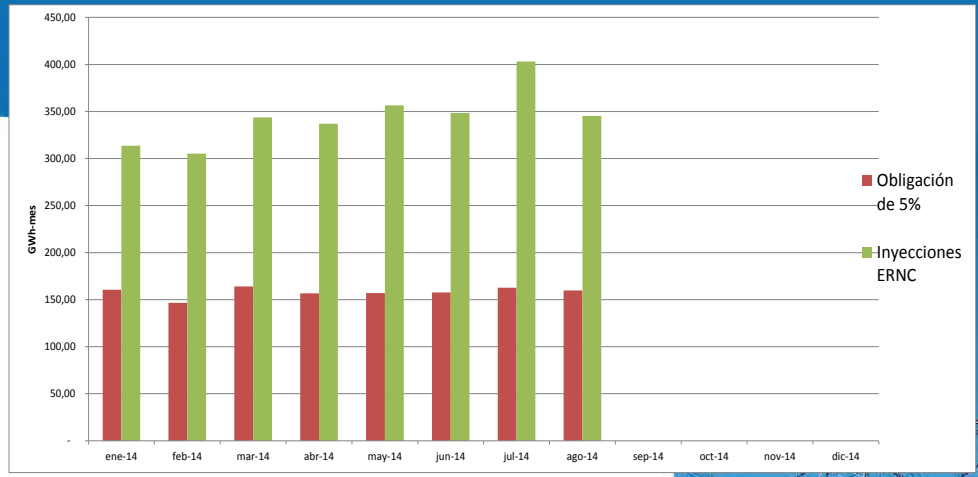
Liquefied Natural Gas

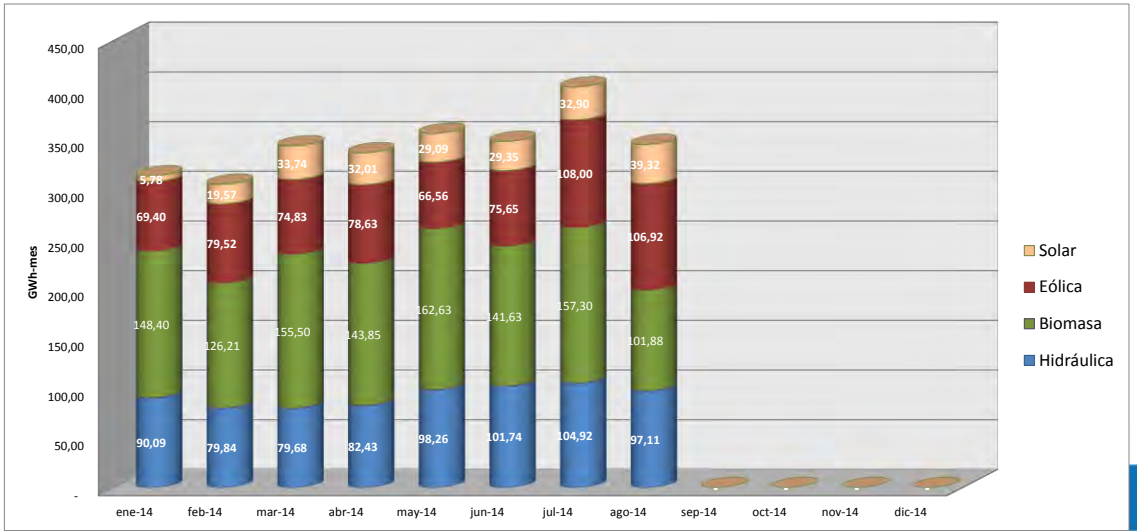
CDEC-SIC

- In Chile, the term “Non-Conventional Renewable Energy” is used to exclude large hydropower (greater than 20 MW) projects from the category “Renewable Energy”.
- In 2013, gross NCRE generation reached 3,986 GWh, including plants recognized under Law 20.257
- In the SIC, wind farms and solar PV power plants are mainly located at the Northern part

BALANCE NCRE



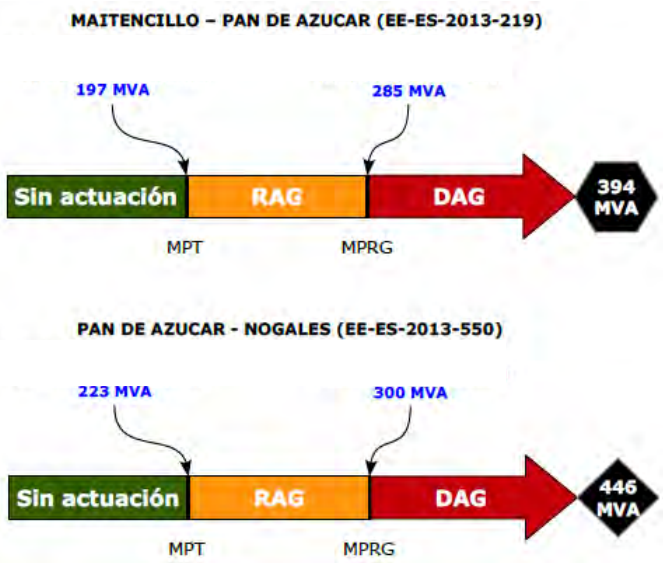




AGENDA

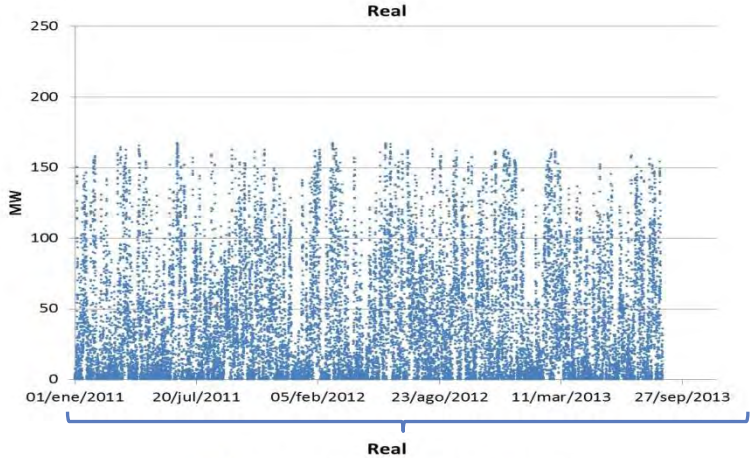
1. GENERAL PRESENTATION.
2. THE NORTHERN PART OF THE SIC: CHARACTERISTICS
   - TRANSMISSION SYSTEM & GENERATION POWER PLANTS
   - WIND GENERATION CHARACTERISTICS
   - WIND GENERATION VARIABILITY
   - 3 HOURS AHEAD FORECAST
   - DAILY SYSTEM DEMAND VARIABILITY
3. NCRE GRID IMPACT: AUTOMATIC SCHEME DESIGN FOR NORTHERN SIC
4. FINAL REMARKS.

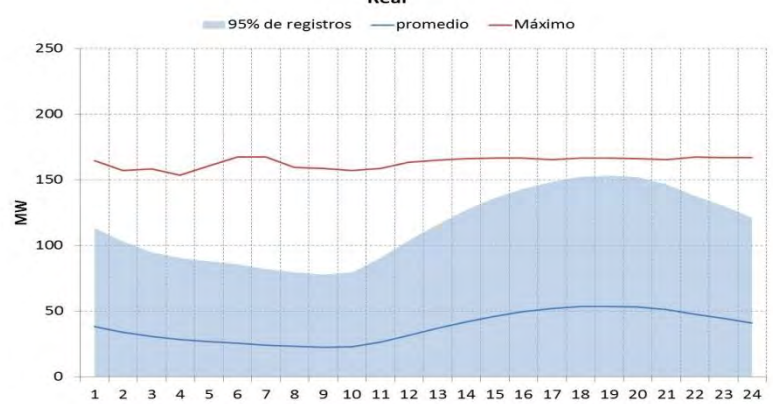
THE NORTHERN PART OF THE SIC: CHARACTERISTICS TRANSMISSION SYSTEM & GENERATION POWER PLANTS



- Conventional Power Plants:
  - Guacolda (4x150 MW Coal Fired Power Plant)
  - Taltal (2x117 MW GT OC LNG & Diesel)
- NCRE Power Plants:
  - Wind Farms “Las Palmas“ Zone : 5 wind farms (485 MW) y 2 wind farms in project (175 MW)
  - Wind Farms “Punta Colorada“ Zone : 1 wind farm (20 MW) y 4 wind farms in project (600 MW)
  - Wind Farms “Taltal “ Zone: : 1 wind farm (60 MW) under commissioning.
  - Solar PV: 2 power plants (100 MW) and around 800 MW under development at North of Cardones Sub-station.

WIND FARM PRODUCTION AND INTRA HOUR VARIABILITY: CANELA 1 Y 2 + TOTORAL + MONTE REDONDO

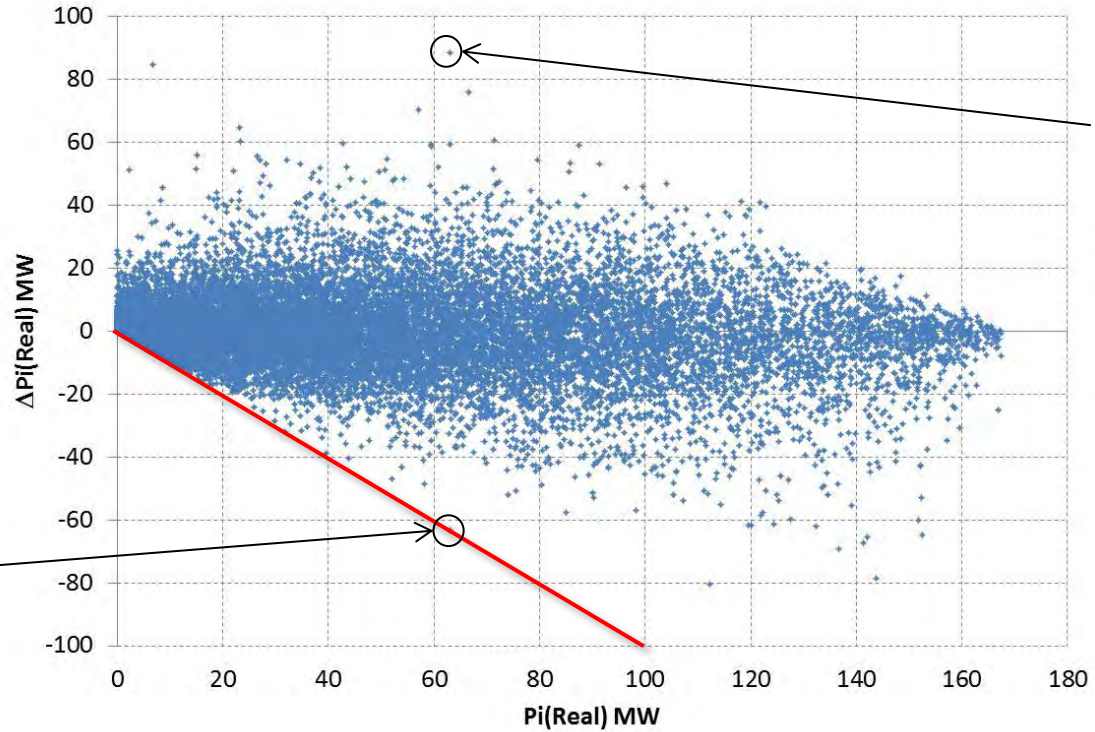




Wind Farm	P_{nom}	$P_{Average}$	σ	Deviation	
				Absolute	Relative
				$\Delta P_{10min/\mu(60min)}$	$\Delta P_{10min/\mu(60min)}$
	[MW]	[MW]	[MW]	[MW]	[%]
Canela I	18	3.0	0.9	2.45	51
Canela II	60	15.2	3.4	9.24	48
Totoral	46	10.4	2.5	6.74	48
Monte Redondo	48	13.0	2.2	5.71	43
Canela I y II Totoral	124	28.6	5.5	14.67	41
Canela I y II Totoral Monte Redondo	172	41.7	6.0	16.00	33

CDEC-SIC

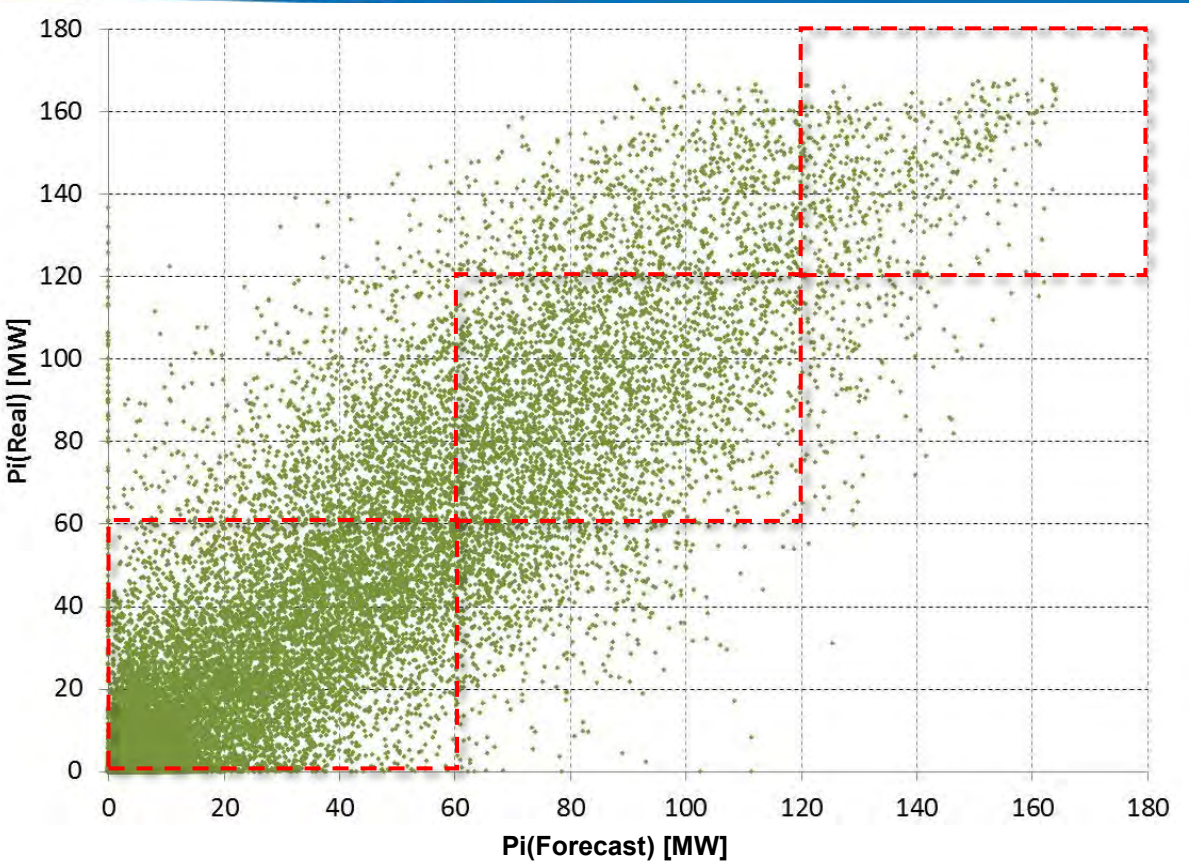
Wind Power Inter-hour variability



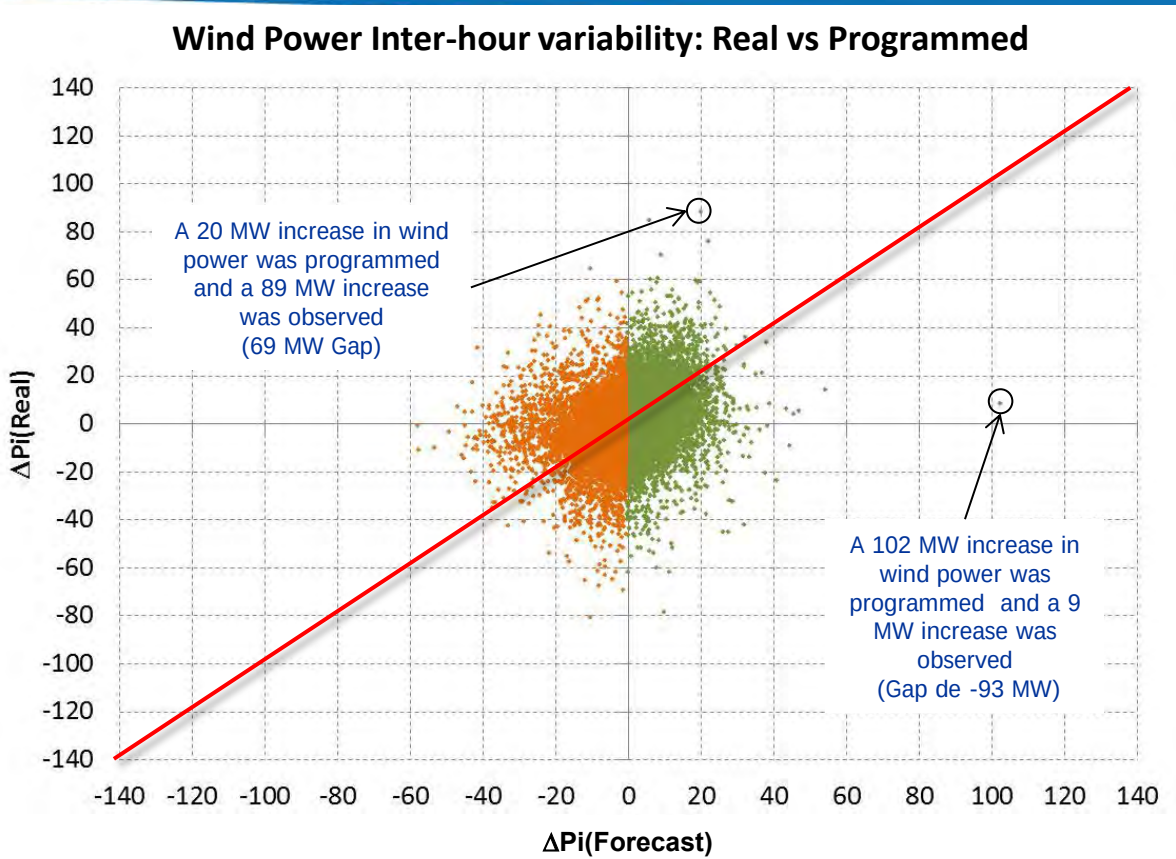
63 MW ouput in an hour and 152 MW output in the next hour

63 MW ouput in an hour and 0 MW output in the next hour

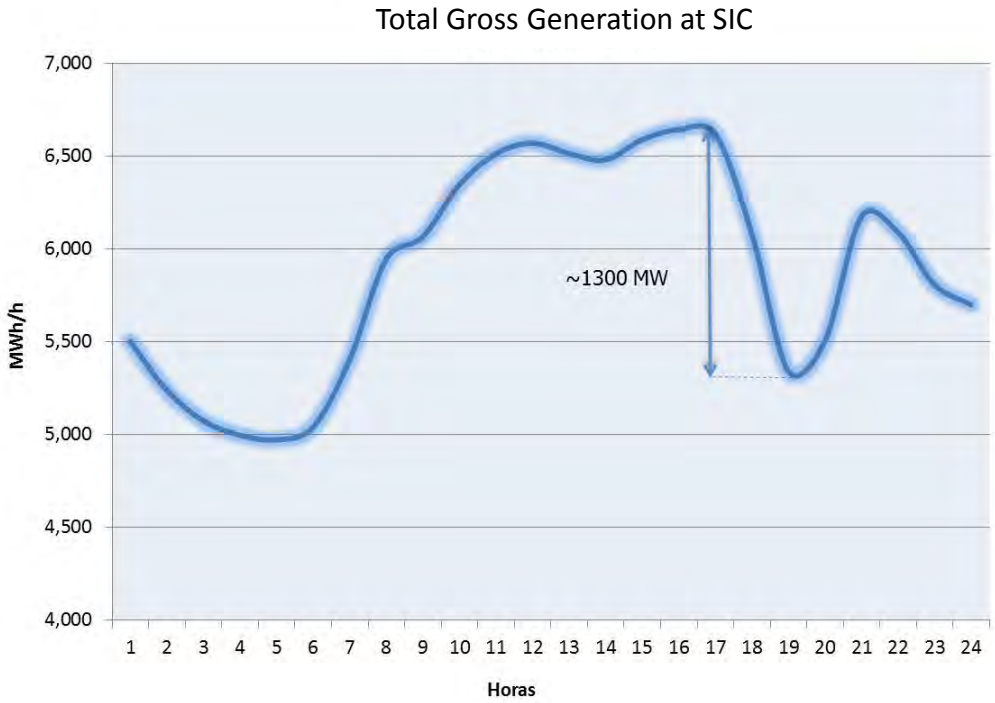
3 HOURS AHEAD FORECAST: FORECAST VS ACTUAL



3 HOURS AHEAD FORECAST: WIND POWER VARIABILITY



- The generation units in service should be prepared to face great change in demand (inter hourly variability)



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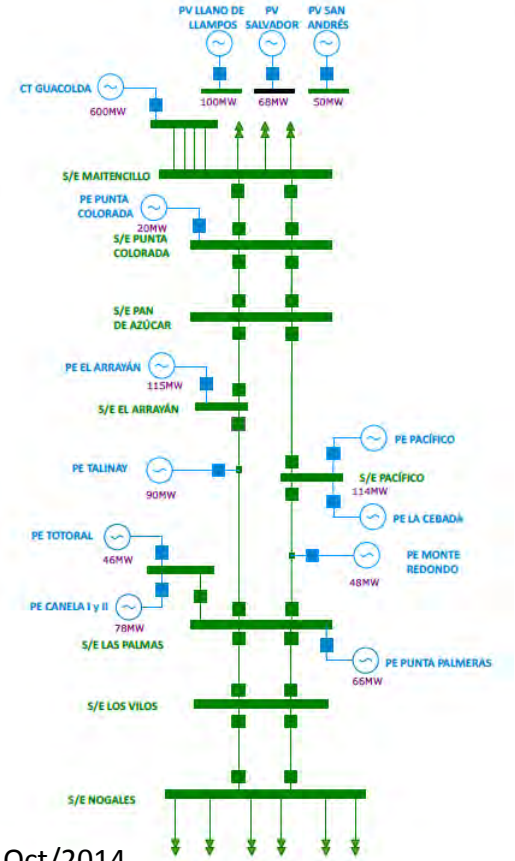
1. GENERAL PRESENTATION.
2. THE NORTHERN PART OF THE SIC: CHARACTERISTICS
3. NCRE GRID IMPACT: AUTOMATIC SCHEME DESIGN FOR NORTHERN SIC
   - OBJECTIVES
   - PERMANENT MONITORING CONTROL SYSTEM
   - EQUIPMENT
4. FINAL REMARKS.

NCRE GRID IMPACT: AUTOMATIC SCHEME DESIGN FOR NORTHERN SIC OBJECTIVES

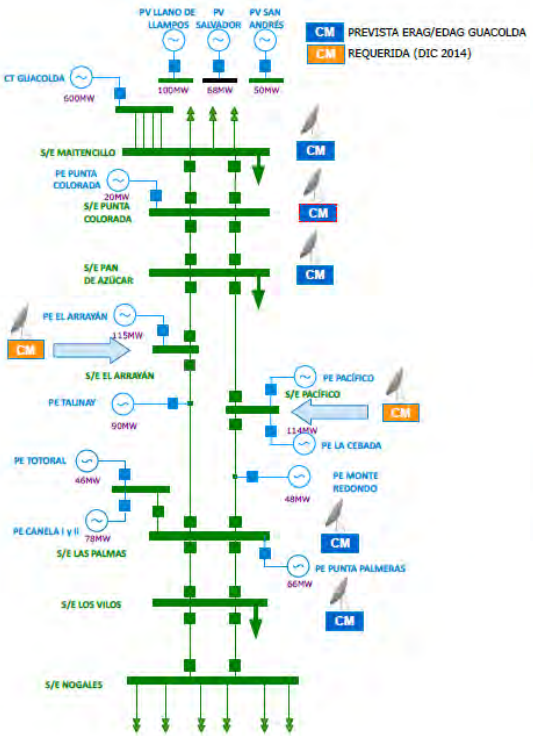
- Automatic scheme study's objectives:
  - Protective and control resources definition to increase technical transmission capacity from northern part of the SIC.
  - To establish transmission threshold under the new protective and control schemes and to compare with current maximum transmission limits.
- Specific objectives:
  - To guarantee the supply of the whole consumers of the zone,
  - To allow the generation of wind power and solar PV, in order to reduce the operation costs of the system.
  - To control the power variation coming from wind farms, making an optimal use of the NCRE in the zone
- Study time horizon: 2014 to 2017.

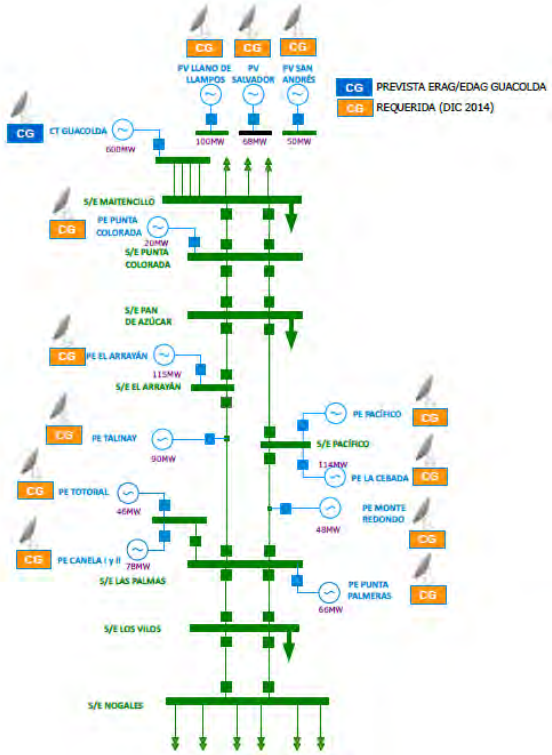
NCRE GRID IMPACT: AUTOMATIC SCHEME DESIGN FOR NORTHERN SIC
PERMANENT MONITORING CONTROL SYSTEM



- Permanent monitoring control system
  - To optimize wind farms power output commanding dynamic constraints, based on the available capacity in the transmission system.
  - In case of short-term or weak overload, produced by external events to the control region (for instance, lost of a great demand outside the security margins adopted), the scheme would command reduction firstly to the wind farms, secondly to Solar PV and at last to Guacolda (conventional coal fired power plant), in order to return to secure operation levels.
  - Whenever the overload levels exceed a threshold for a while, the scheme will act commanding reduction or disconnection to wind farms, Solar PV power plants and eventually to Guacolda power plant.

AUTOMATIC SCHEME NORTHERN SIC : EQUIPMENT





- As a starting point the scheme used the equipment associated to a previous automatic scheme developed to act over Guacolda power plant.
- **Monitoring Cell** : Its function is to compile and to transmit signals to the “General Control Cell”.
- **Generation Cell**: Its function is to compile signals from power plant and to transmit these signals to the “General Control Cell” and interact with the SCADA of each power plant, in order to assign a limit/reduction/disconnecction role.
- **General Control Cell**: Its function is to compile every signal sent by the other cells, to process the information to determine the actions required and eventually send operation commands to each “Generation Cell”.

AGENDA

1. GENERAL PRESENTATION.
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4. FINAL REMARKS.

- The main objective of the scheme is to increase the use of transmission capacity from NORTH → SOUTH, allowing maximum generation from NCRE sources.
  - 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.
- Summing up, the scheme commands the reduction or disconnection of pre-selected power plants, located in the "electrical North" of the link affected by a contingency, according to the next priorities:
  1. Wind Farms
  2. Solar PV power plants
  3. Conventional units: Guacolda or Taltal
- Why these priorities? :
  - The system must reach an stable condition as soon as possible after a contingency.
  - Under the aforementioned premise, the use of NRCE generation is not imperative and in some cases the natural variation of its generation offer could negatively affect system control.
  - It becomes a priority to ensure short-circuit levels, inertia and power reserves; therefore, conventional generation will be restricted only as a last resource.

CDEC-SIC

THANKS