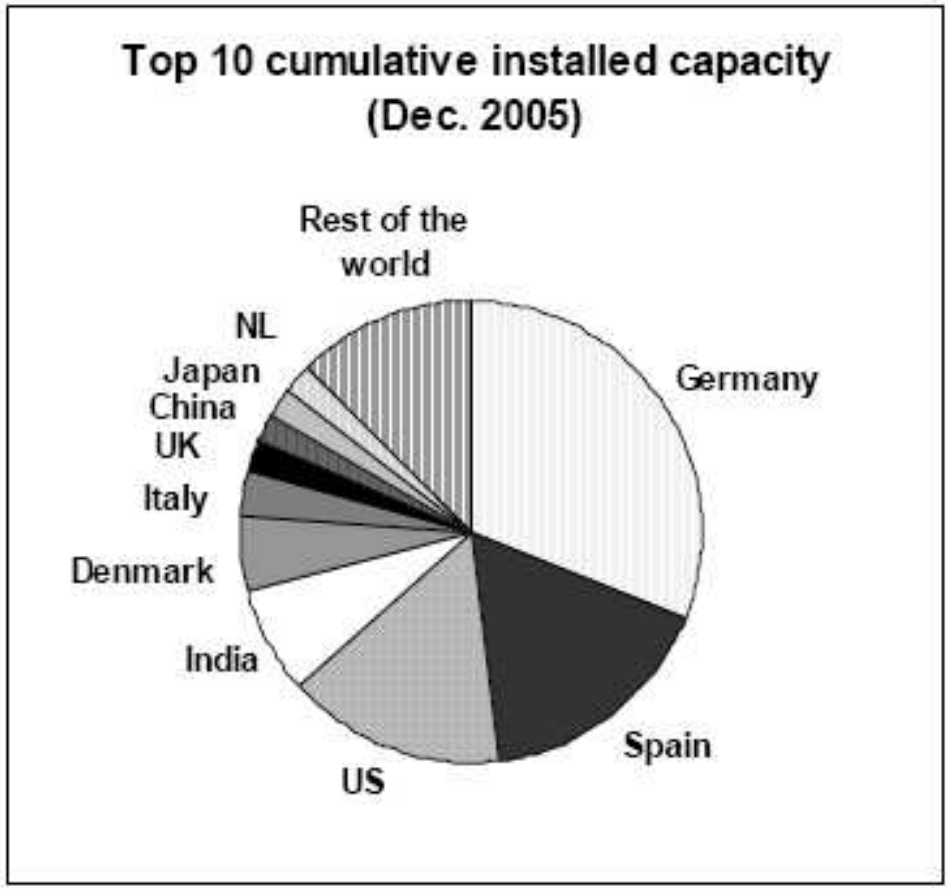
# Wind Power and Grid Integration
# The Spanish Experience
## 风力发电与电网整合——西班牙的经验

*EUCCC Wind Power Workshop*

*Beijing, 15 March 2007*

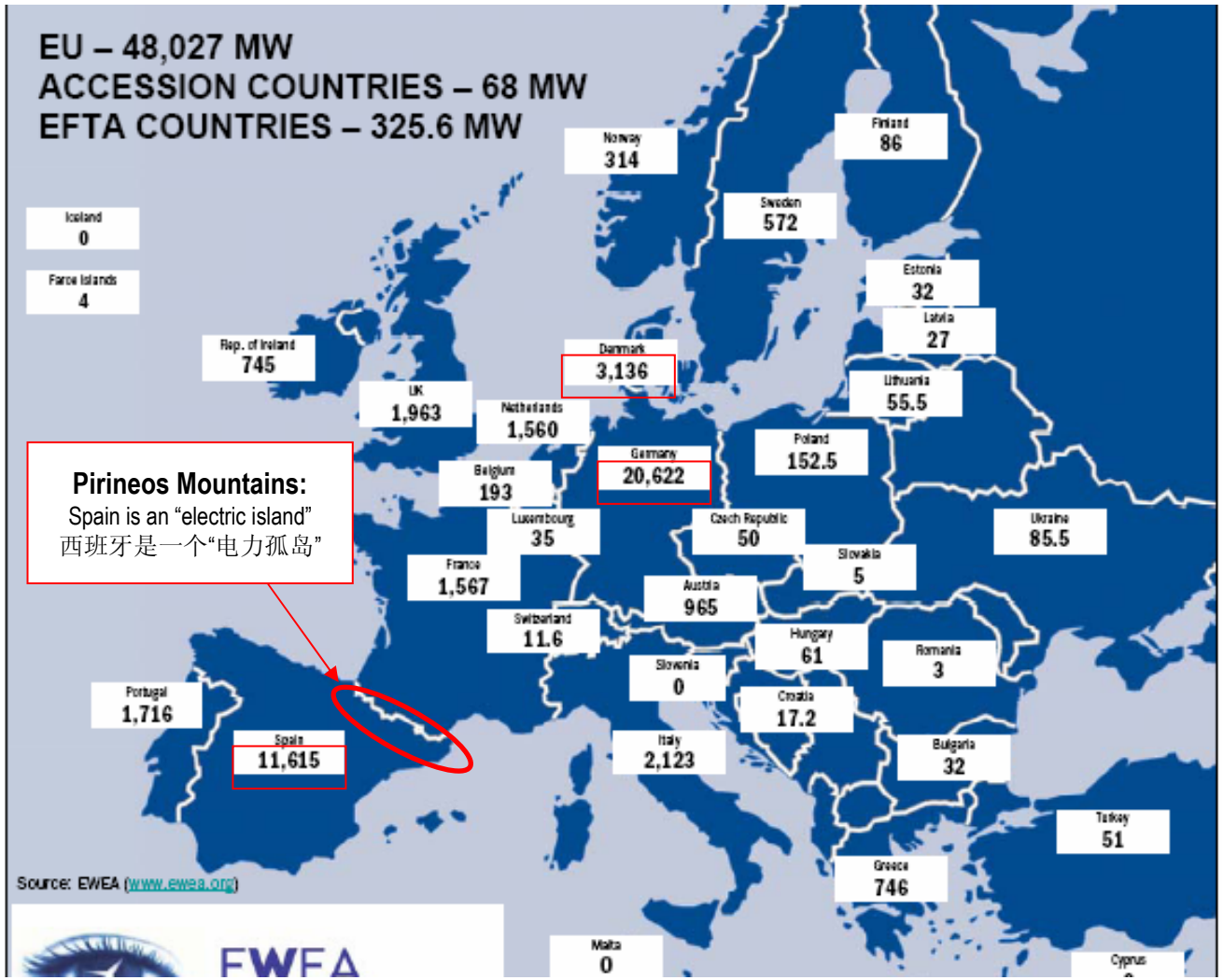
# Index 目录

# 1. Introduction. Worldwide wind power installed capacity
# 简介: 全球风电装机容量




| Total capacity | MW | % |
|---|---|---|
| Germany | 18,428 | 31.0 |
| Spain | 10,027 | 16.9 |
| US | 9,149 | 15.4 |
| India | 4,430 | 7.5 |
| Denmark | 3,122 | 5.3 |
| Italy | 1,717 | 2.9 |
| UK | 1,353 | 2.3 |
| China | 1,260 | 2.1 |
| Japan | 1,231 | 2.1 |
| NL | 1,219 | 2.1 |
| Top 10 – Total | 51,936 | 87.5 |
| Rest of the world | 7,368 | 12.5 |
| World total | 59,322 | 100 |

# 1. Introduction. European wind power markets in 2006
# 简介：2006年欧洲的风电市场

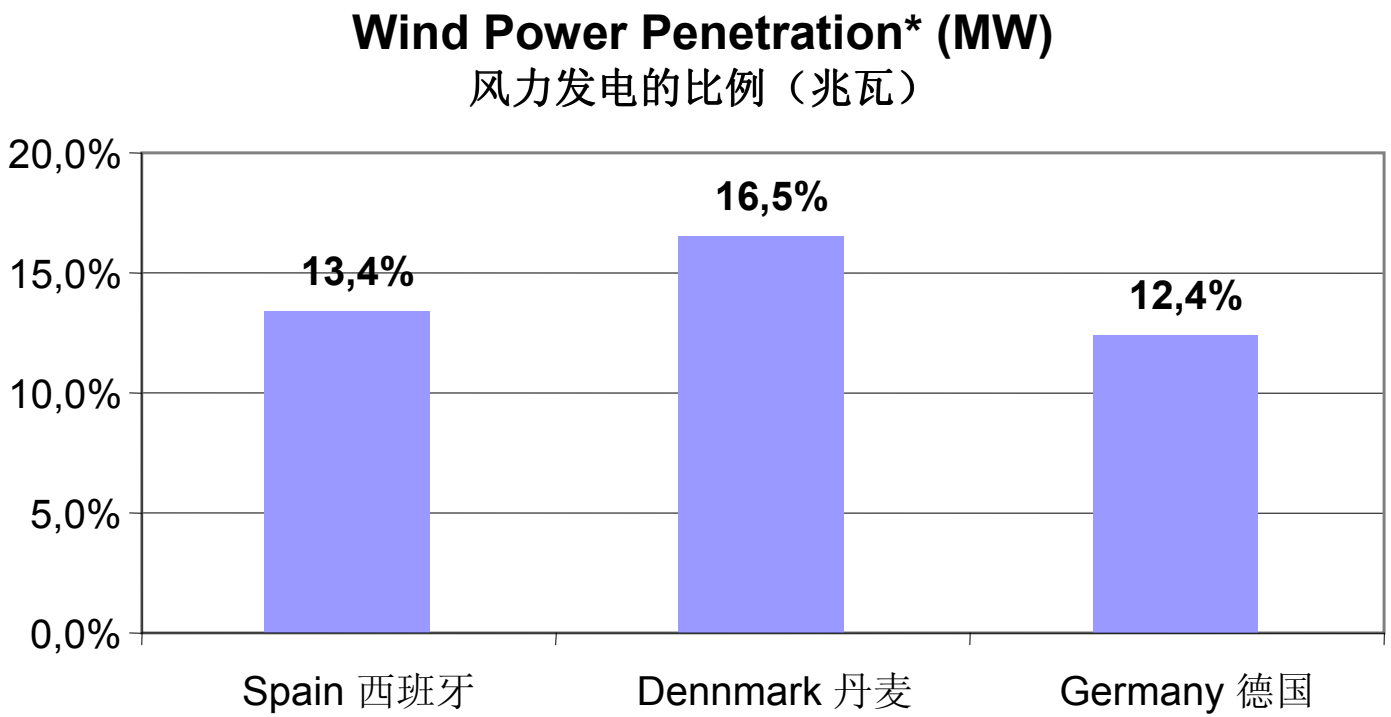


# 1. Wind power penetration in leading European markets*
# 风力发电在主要的欧洲市场中的比例（见下表最后一列）

| Country 国家 | Installed Capacity (MW) 网内装机容量 | Interconnection Capacity (MW) 外送电容量 | Total Installed + Interconnection Capacity (MW) 总装机容量 | Total Installed Wind Power (MW) 风电装机容量 | Wind Power Capacity / Total Capacity (MW) 风电装机/网内容量 | Wind Power Capacity / Total Installed + Interconnection Capacity (MW) 风电容量/总容量 |
|---|---|---|---|---|---|---|
| **Spain** 西班牙 | **72 862** | **2 200** | **75 062** | **10 027** | **13,8%** | **13,4%** |
| **Dennmark** 丹麦 | **14 031** | **4 890** | **18 921** | **3 122** | **22,3%** | **16,5%** |
| **Germany** 德国 | **130 037** | **18 650** | **148 687** | **18 428** | **14,2%** | **12,4%** |

* Source: Eurostat & Gamesa Analysis. 2005

# 1. Wind power penetration in leading European markets (II)
# 风力发电在主要的欧洲市场中的比例（II）




* Including interconnection capacity. 2005

# 1. Why grid integration has been a great challenge in Spain?
# 为什么电网整合对于西班牙来说是一个巨大的挑战？

- Atlantic low pressure fronts can make the instant wind power generation change from a few hundreds to several thousands of MW in a few hours

  大西洋的低压气流可以使风力发电的瞬时发电量在几个小时内从几十万千瓦增至几百万千瓦

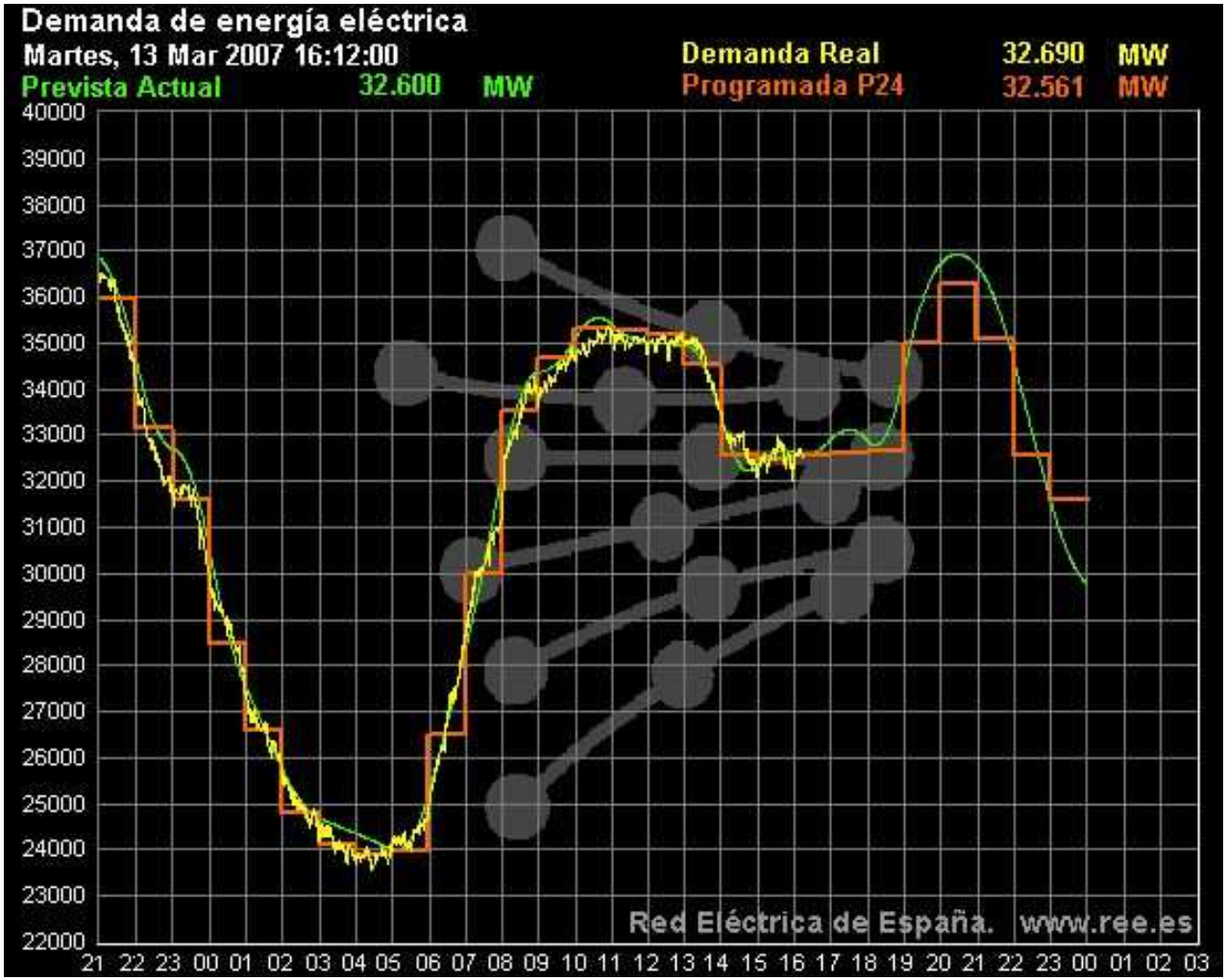
- Because the wind power penetration is really high (+15% as of today, 2nd largest worldwide)

  风力发电的装机容量在全国的总装机容量中占的比例很高 （目前已超过15%，位居世界第二）

- Because Spanish is an “electrical island”: only 3% net interconnection capacity with neighbor countries

  西班牙是一个“电力孤岛”，仅可以从周边国家得到3%的电量

# 2. Main Challenges. Adjusting Generation and Demand (I)
# 挑战：调整电力供应与需求（I）




- Demand Forecast
  电力需求预测
- Generation Program
  电力供应程序
- Real-Time Demand
  实时电力需求

# 2. Main Challenges. Adjusting Generation and Demand (II)
# 挑战：调整电力供应与需求（II）

- Problems:

  问题:

  - Wind power generation output cannot be governed (it depends of the wind speed in every moment)

    风力发电的发电量无法管理（发电量主要依靠当时的风速）

  - As a result, the instant wind power generation in Spain can vary from a few hundreds of MW to +9.000 MW (up to 30% of the instant power demand) in only a few hours

    在西班牙，风力发电的瞬时发电量在几个小时内可以从几百MW增至+9,000 MW （相当于瞬时电力需求增长30%）

  - In order to manage the total stability of the electrical system, this fluctuations must be managed

    为了保证整个电力系统的稳定性，这种起伏需要得到控制

# 2. Main Challenges. Adjusting Generation and Demand (III)
# 挑战：调整电力供应与需求（III）

- Solutions:

  结论：

  - Development of short term wind resource prediction model

    发展短期风力资源预测系统

  - Every wind farm has to summit to the System Operator (Red Eléctrica de España) the production forecast (generation program) for every hour of the day ahead.

    每个风力发电场需向系统管理员（西班牙国家电网公司）提交下一天每个小时的发电量预测

  - The wind power day ahead program is added to the country's generation program (coal, gas, nuclear, hydro) and adjusted to match the demand forecast

    风力发电的预测程序会被加入到整个国家的电力控制程序（包括火电、核电、水电），并根据用电量需求的预测进行调整。

# 2. Main Challenges. Adjusting Generation and Demand (IV)
# 挑战：调整电力供应与需求（IV）

- Solutions:

  结论：

  - In this way the System Operator only has to manage the deviations between programmed and real wind power generation using the power regulation protocols as usual.

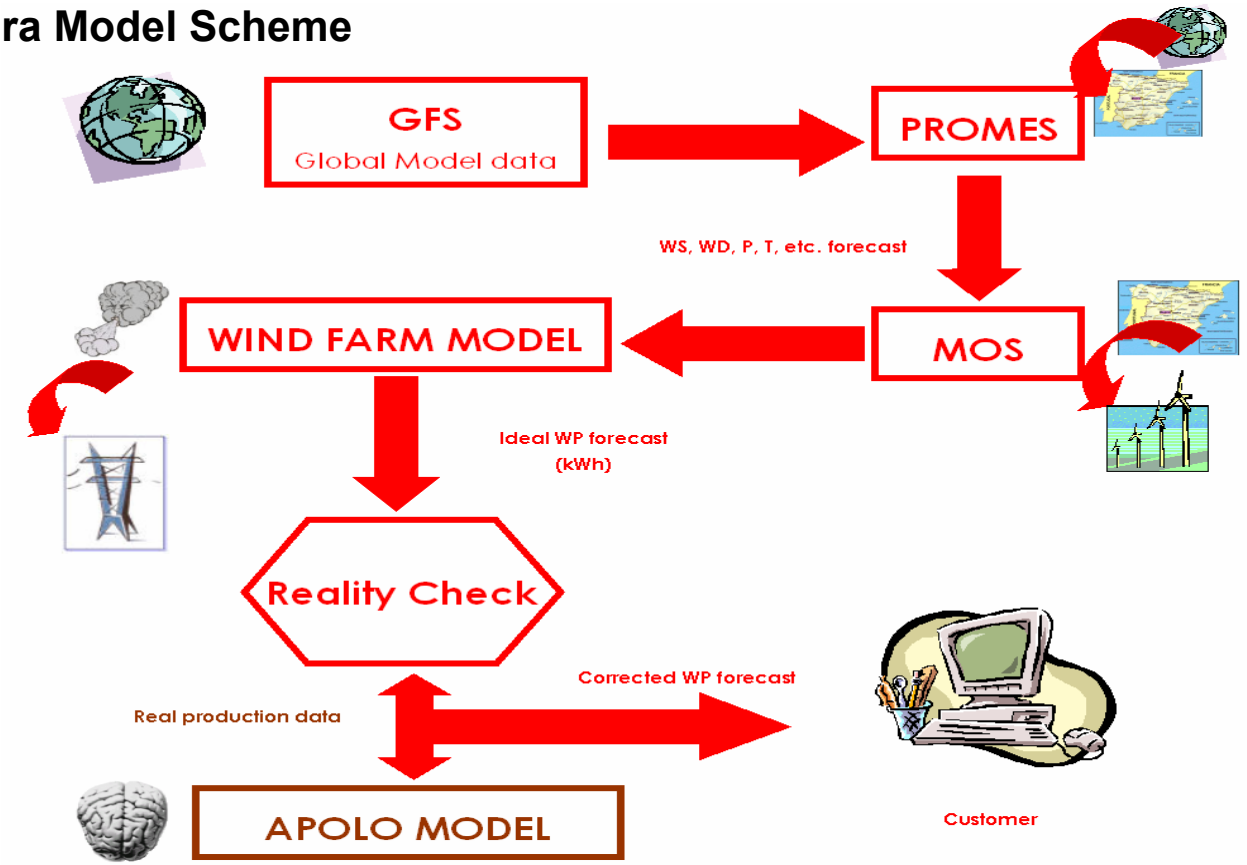
    系统操作员可以利用已有的供需模式，仅在风力发电预测与实际发电量之间做出调整即可

  - Economic Signal: the wind farms have to pay a penalty for the deviations between the programmed and the real generation every hour (typical errors are between 10% to 20%).

    经济手段：若风力发电场提供的每小时的发电量预测与实际发电量不符，风力发电场需支付一定的罚金（偏差率可在10%到20%）。

# 2. Main Challenges. Adjusting Generation and Demand (V)
# 挑战：调整电力供应与需求（V）

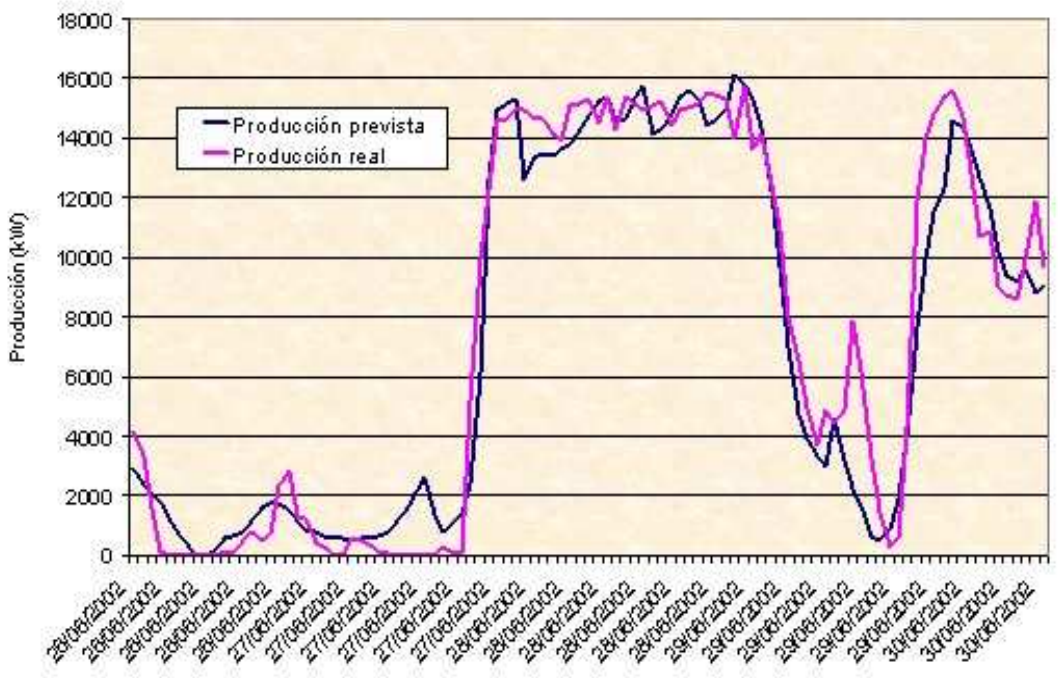
**Can a wind energy forecast tool be accurate on the one/two day ahead timeframe?**
**风力发电预测工具是否可以提前一天或两天准确的预测发电量？**
**Casandra example：**
**Casandra Model Scheme**



# 2. Main Challenges. Adjusting Generation and Demand (VI)
# 挑战：调整电力供应与需求（VI）

CASANDRA

La Plana W.F. (18 MW), Aragón, Spain



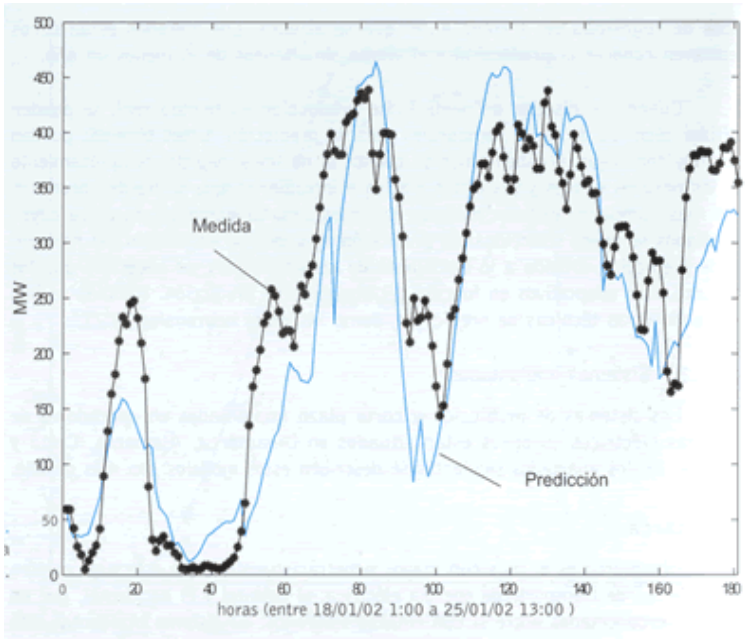

Commercial simulation model developed by Gamesa for forecasting of wind generation

(to be applied for WF which want to make energy bids to the electrical market)

歌美飒公司开发的预测风力发电量的商业化模拟系统

SIPREOLICO

Spanish Wind Farms

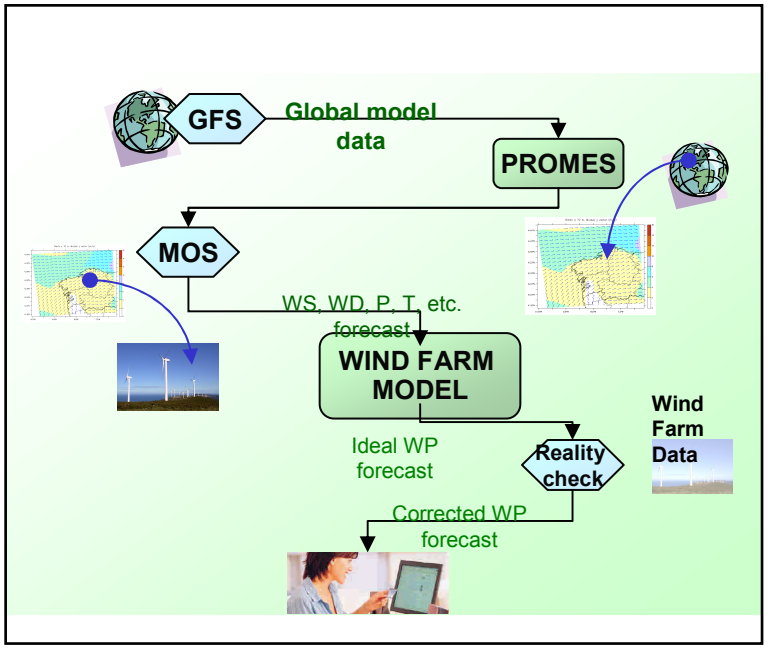



Simulation model developed by REE with on-line measurements taken from Spanish WF

REE开发的模拟系统

# 2. Main Challenges. Adjusting Generation and Demand (VII)
# 挑战：调整电力供应与需求（VII）

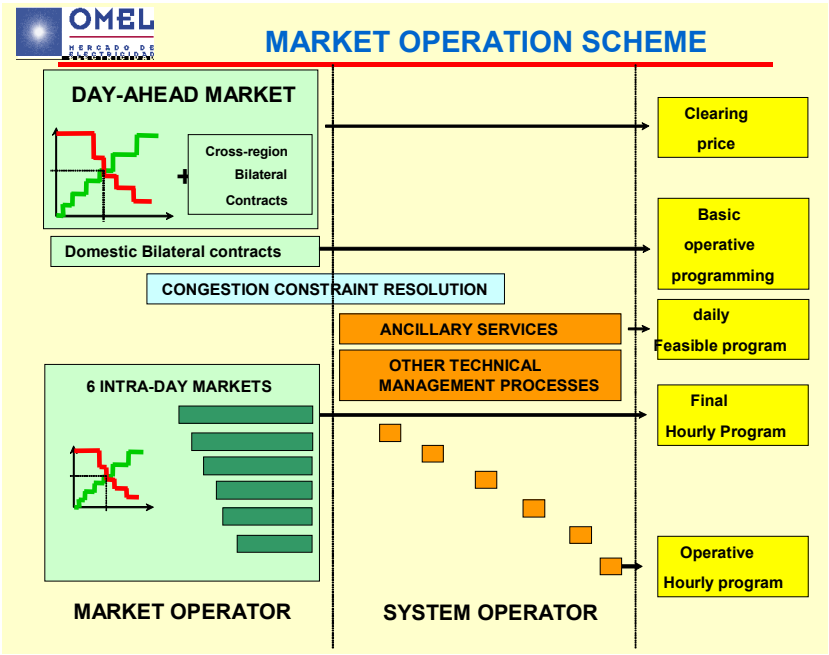
## Predictions of the meteorological model
## 气象预测系统




**Best forecast possible**

尽可能完善的预测

## Simulation tool of market behaviour
## 市场模拟工具




**Minimization of deviation costs & maximizing income**

偏差成本最小化 与 收入最大化

# 2. Main Challenges. Voltage Dips (I)
# 挑战：电压骤降（I）

- Problem:

  问题：

  - Because of shortcuts in the HV lines, temporary voltage dips happen in the electrical system

    由于高压线路短路，电力系统经常会发生暂时性的电压急剧下降

  - This voltage dips trigger the protection systems of the wind turbines, disconnecting the wind farm from the grid

    这种电压的急剧下降会触发风机的自我保护系统，并使整个风电场掉网

  - In some areas of Spain, and under some circumstances this could mean loosing thousands of MW of instant power generation in less than 1 second.

    在西班牙的一些地区，这意味着在1秒钟的时间内可能会损失几百万千瓦的发电量。

# 2. Main Challenges. Voltage Dips (I)
# 挑战：电压骤降（I）

- Solution:

  结论：

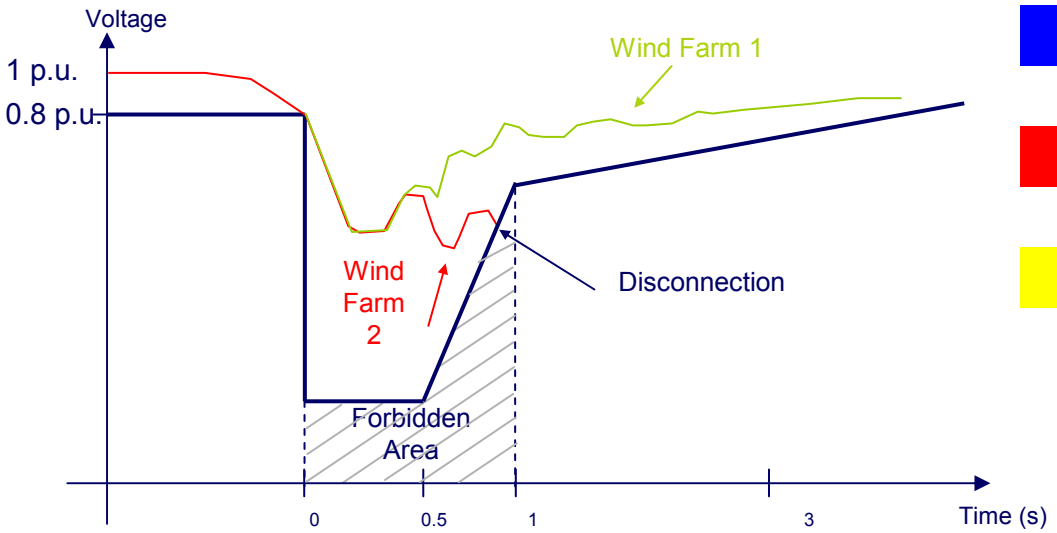
  - Development of the “Active Crowbar” technology, which provides the wind turbine “Ride Through” capabilities

    发展“有效撬棍”技术，使风机具有“跨越”电压骤降的能力

  - Economic Signal: wind farms with “Ride Through” technology receive a higher price for the electricity generated

    经济手段:具有“跨越”电压骤降技术的发电场，所发电量的价格略高于无此技术的电场

# 2. Main Challenges. Voltage Dips (I)
# 挑战：电压骤降（I）




Reference Voltage Dip TSO
电压骤降参考

Evolution without Ride Through Tech.
无跨越技术

Evolution without Ride ThroughTech.
有跨越技术

# 2. Main challenges. Voltage and reactive power regulation
# 挑战：电压和无功功率调节

- Problem:

  问题：

  - Initially, wind turbines could not regulate voltage, nor reactive power, resulting more electrical loses and a less stable grid behavior

    最初，风力发电机不能够控制电压或无功功率，因此会造成更多的电力损失并使电网的稳定性下降

- Solution:

  结论：

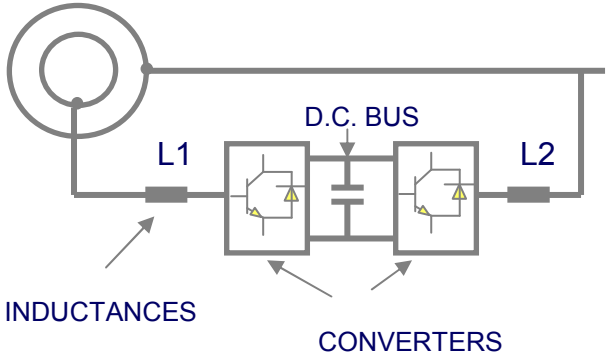
  - Development of power electronics for generators allowing reactive power and voltage control

    发展电子发电机以便控制无功功率及电压的起伏

# 2. Main challenges. Voltage and reactive power regulation
# 挑战：电压和无功功率调节

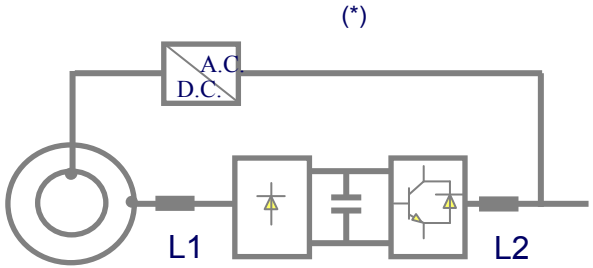
• DOUBLE-FED INDUCTION (DFIG) (GE,Gamesa, Vestas)
双馈感应发电机（GE,Gamesa, Vestas）

**Advantages**: variable speed (more efficiency), reactive control, low harmonic (only 10% power through converters)
优点：可变速发电效率较高，功率因数可调，谐波污染




• SYNCHRONOUS FULL POWER (Enercon)
同步发电机（Enercon）

**Advantages**: variable speed, reactive control
优点：可变速，功率因数可调
**Disadvantages**: more expensive, harmonics
缺点：价格昂贵，



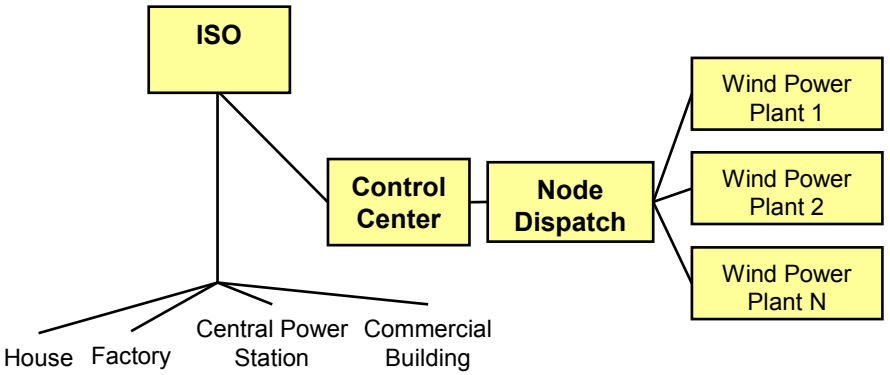

(*) Excitation no necessary, if the generator has permanent magnets at the rotor.

# 2. Main challenges. Integration of wind farms in load control centres
挑战：风电场整合控制中心

- In order to integrate the energy, the operational information must be also integrated: 为了整合能源，控制信息也必须要整合：

## System Structure:

系统结构：




## Renewable Energy Control Centers*:

可再生能源控制中心：

*Center for Operation of Renewable Energies (CORE). Iberdrola. Spain*

# 3. Final Results 结果

- In Spain wind power is not an alternative energy anymore. It is a conventional power generation source fully integrated in the electrical system, which accounts for a large part of the country's consumption

  在西班牙，风能已不再是补充能源。他已经成为电力系统的常规能源之一，并在全国的发电量中占有很大的比重。

- Today, more power is generated in Spain by means of wind power than by means of hydro power

  目前，西班牙风能所发出的电量要高于水力发电。

- At the same time, the power supply quality has not been affected at all. Spain has a world class electrical system:

  同时，供电质量并没有因此而下降。西班牙拥有世界级的电力系统。

  - As of 2005 the equivalent yearly interruption time was only 2.18 min. (this means a 99,9996% reliability)

    2005年，全年平均电力中断仅为2.18分钟（可靠性99.9996%）。

# 3. Final Results 结果

- This has been thanks to:

  所有这些应归功于：

  - Strong and successful cooperation between all the industry stakeholders: System Operator engineers, Wind Power engineers, power generation engineers and other experts working together

    电力行业里所有参与者的通力合作，包括系统操作工程师、发电工程师、风电工程师及所有专业人士。

  - Demanding grid codes and technology standards

    高要求的电网规则及技术指标

  - Correct economic signals for the market players

    正确的经济手段

# 4. Conclusions and recommendations based on the Spanish Experience

从西班牙的经验中得出的结论及建议

- Although today it is not a problem in China, the amazing development of wind power in China will eventually put stability constraints in the electrical systems in the mid term

  尽管中国目前还没有面临这个问题，但飞速发展的风力发电产业将在未来的几年内对电力系统的稳定性产生影响

- In order to face this challenge, China should start to work on it ASAP

  为了更好地面对挑战，中国应开始着手准备

- Involve all the players in the industry to guarantee success: not only State Grid Corporation, but also WTG Manufacturers, WF developers and Power Generation Companies

  调动此行业中的所有参与者以保证挑战的成功，这不仅是国家电网公司的责任，也包括了风机的制造商，风力发电场的开发商及所有的发电公司。

# 4. Conclusions and recommendations based on the Spanish Experience
从西班牙的经验中得出的结论及建议

- To define, develop and implement:

  定义、发展、实施：

  - Advanced grid codes

    先进的电网规则

  - Demanding technology standards: “Ride Through” technology, power electronics, reactive power control, etc.

    高规格的技术标准：“跨越”技术、工业电子、无功功率控制等

  - Right economic signals: penalties for deviations, incentives for high quality energy, etc.

    正确的经济手段：对偏差的惩罚、对高质量能源的奖励等。

# Muchas Gracias!

**Thank you!**

谢谢!