Technical Impacts of Large Scale Wind Penetration on Electric Power Systems – Roadmap for Greece and Coordinated Activities in South Eastern Europe

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WIND POWER

- The most promising source for achieving 20% of RES penetration
- Is becoming fast a major primary source than a marginal
- Main Energy Policy line in EU
- Support policies (priority to dispatch, fixed feed-in tariffs, etc.)
- WFs are expected to have the largest share

THE TSO POINT OF VIEW

Large wind penetration

- Technically a new challenge
- Impact on ESI economics and the Market

Key issue:

- volatility and uncontrollability of primary energy
- Low availability
- Random nature of wind
- Significant TECHNICAL and ECONOMIC impacts are expected

CRUCIAL TECHNICAL ISSUES

- Load following (automatic generation control and frequency regulation)
- Coordination with conventional thermal generators
- Transmission capacities
- Monitoring and Control by Energy Management Systems
- Voltage regulation (in HV and MV level)
- WF behavior in normal operation and during contingencies
- Impacts on electricity exchanges and trading
- **TSOs should be prepared to face these challenges**

OTHER ISSUES

- Impact on static stability (reduced frequency oscillation modes and impact on system damping).
- Impact of hydro thermal scheduling
- Increase of short circuit power at the points of connection
- Protection resetting in the distribution network

LOAD FOLLOWING & FREQUENCY REGULATION (I)

- Random primary energy of high volatility
- P=L to achieve «constant» frequency
- Need to follow the load variations. Today WFs do not contribute to Automatic Generation Control
- Increased needs for reserves (especially secondary and tertiary) under high wind penetration
- Increased cost of reserves
- Increased flexibility of conventional generators is required to minimize wind power curtailments

LOAD FOLLOWING & FREQUENCY REGULATION (II)

Modern WTGs are capable to contribute to AGC through:

- Fast pitch actions
- Switched loads
- Speed regulation of wind turbines with power electronic interface

COORDINATION WITH CONVENTIONAL THERMAL GENERATORS

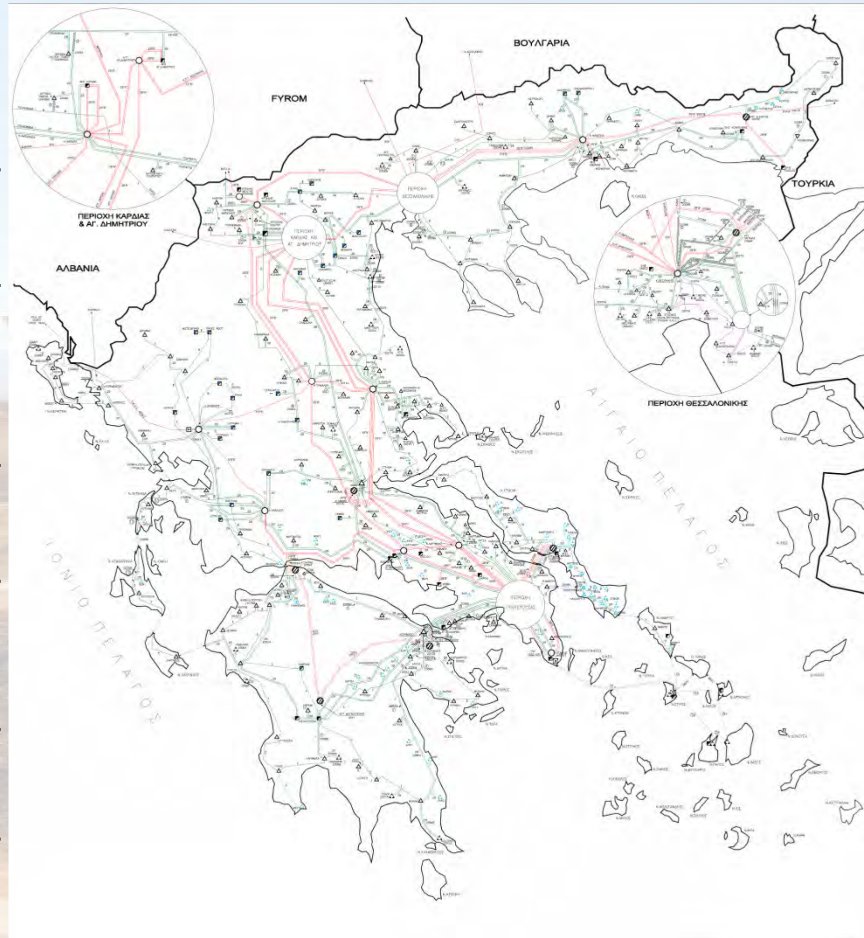
- Technical minimum (usually a hard constraint)
- Ramp up / down rates
- Start up / shut down times
- Avoid often start / stop of steam and CC generators

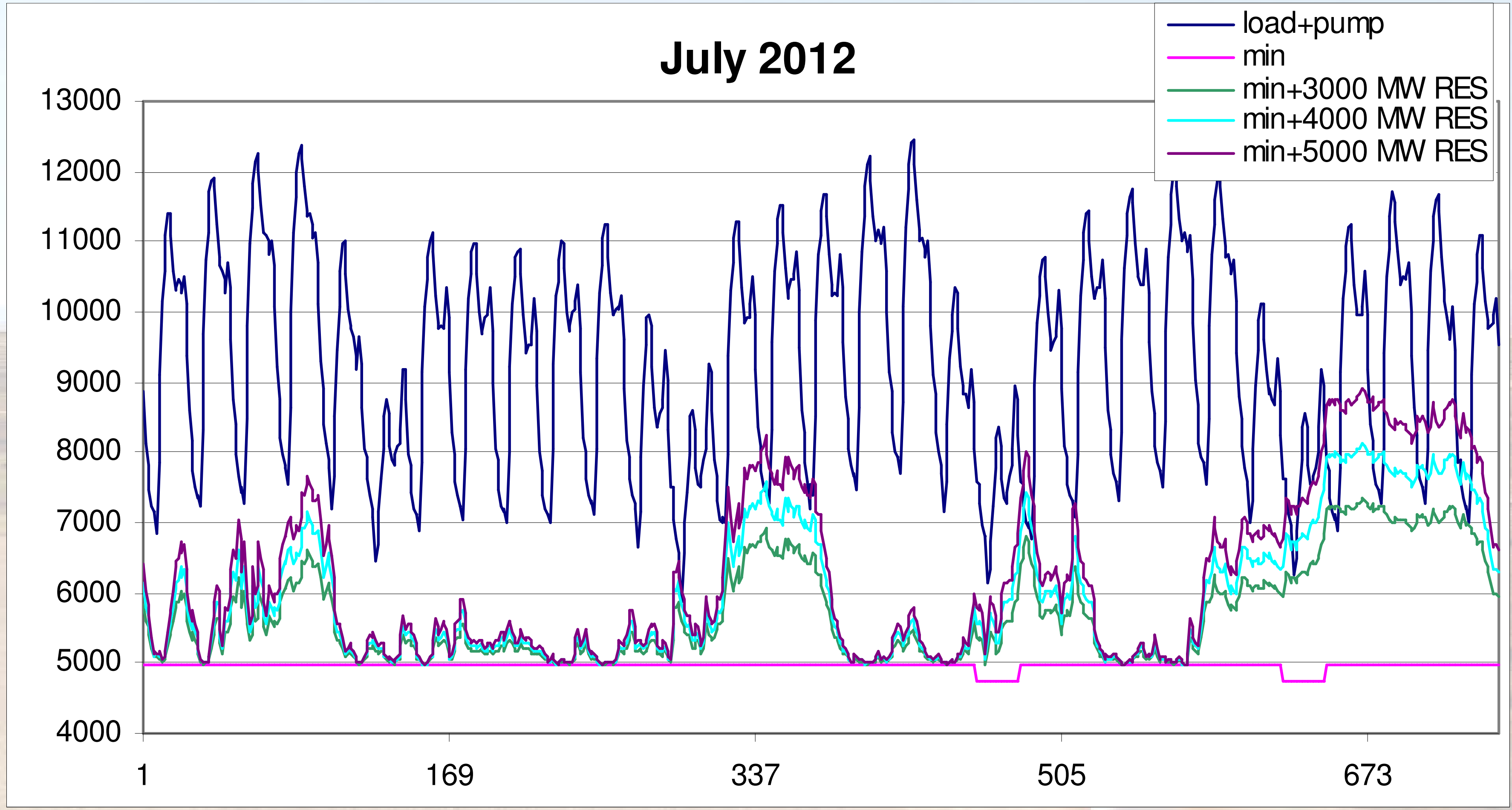
➢ Need for more peaking power (hydros, open cycle gas turbines)

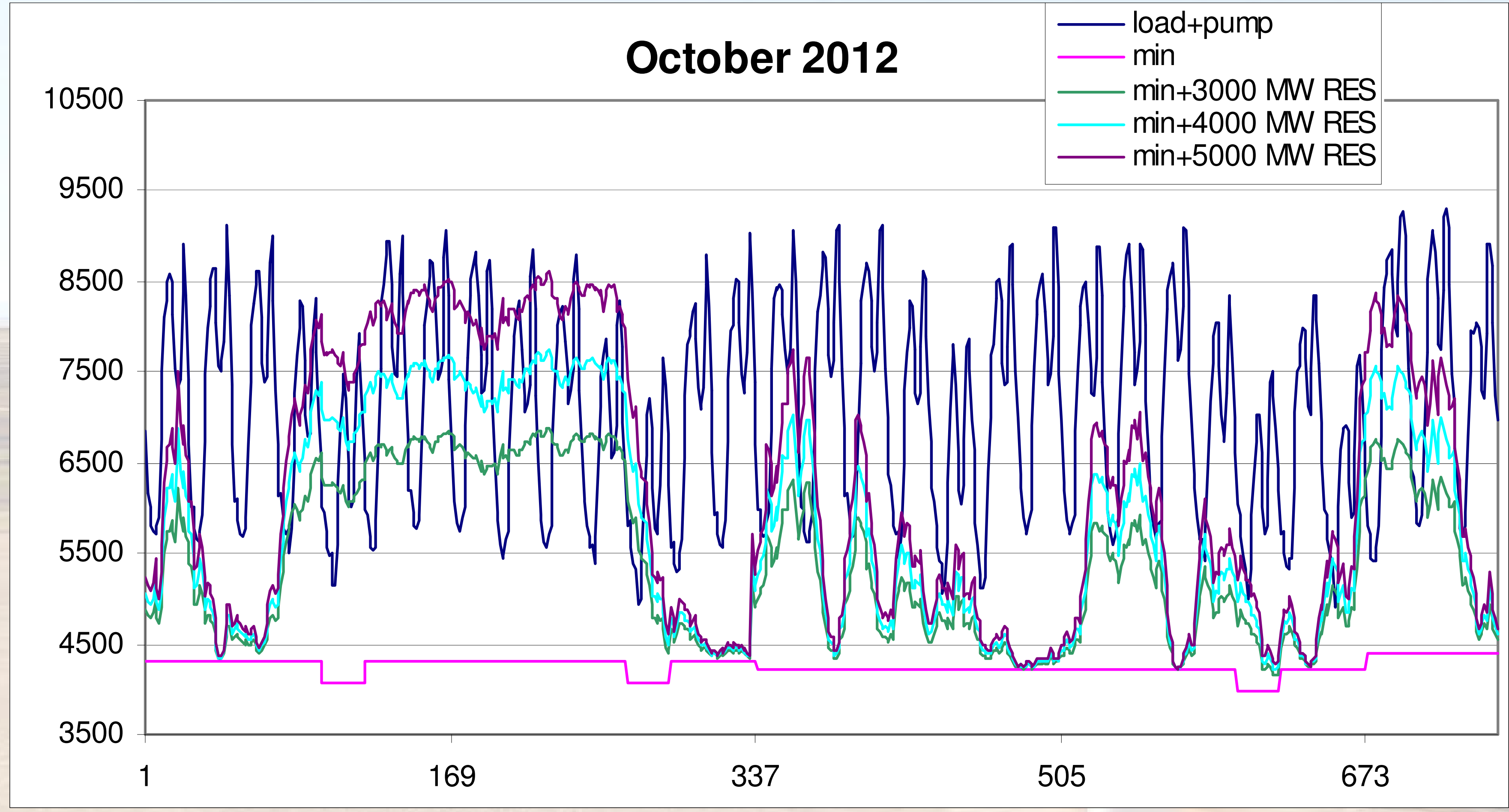
EXAMPLE: GREECE

Production-mix

Type	Net capacity (MW)	Technical minimum (MW)
Thermal generation	7980	4458
Lignite	*4808*	*2841*
Oil	*718*	*430*
Natural Gas	*1532*	*1087*
Gas turbines	922	
Hydro Generation	3057	
With reservoirs	*2442*	
Pump storage	*615*	
RES	771	
Wind	*640*	
Small Hydro	*100*	
Biomass-Biogas	*31*	
Co-generation	113	
Total	11921	4458




July 2012
load+pump
min
min+3000 MW RES
min+4000 MW RES
min+5000 MW RES
13000
12000
11000
10000
9000
8000
7000
6000
5000
4000
1
169
337
505
673


October 2012
load+pump
min
min+3000 MW RES
min+4000 MW RES
min+5000 MW RES
10500
9500
8500
7500
6500
5500
4500
3500
1
169
337
505
673

Transmission capacities

- Transmission capacities needed from wind areas to the System boundaries.
- In windy areas human activity is limited, i.e. weak network infrastructures
- Cost issues
  - Who bears the cost?
  - Licensing, Authorization/land use
  - Construction
- Spatial distribution of WFs at the planning phase is crucial
- Delays in transmission projects materialization due to time consuming licensing procedures and strong protest

VOLTAGE REGULATION

Local Problem especially with asynchronous WTGs (absence of self-excitation)

Extended use of:

- Capacitors mechanically switched
- SVCs (in extreme cases i.e. off-shore, long connection lines)
- PWM technology offers interesting possibilities for power factor regulation and voltage support.
- Voltage stability is a crucial issue for areas with high wind penetration

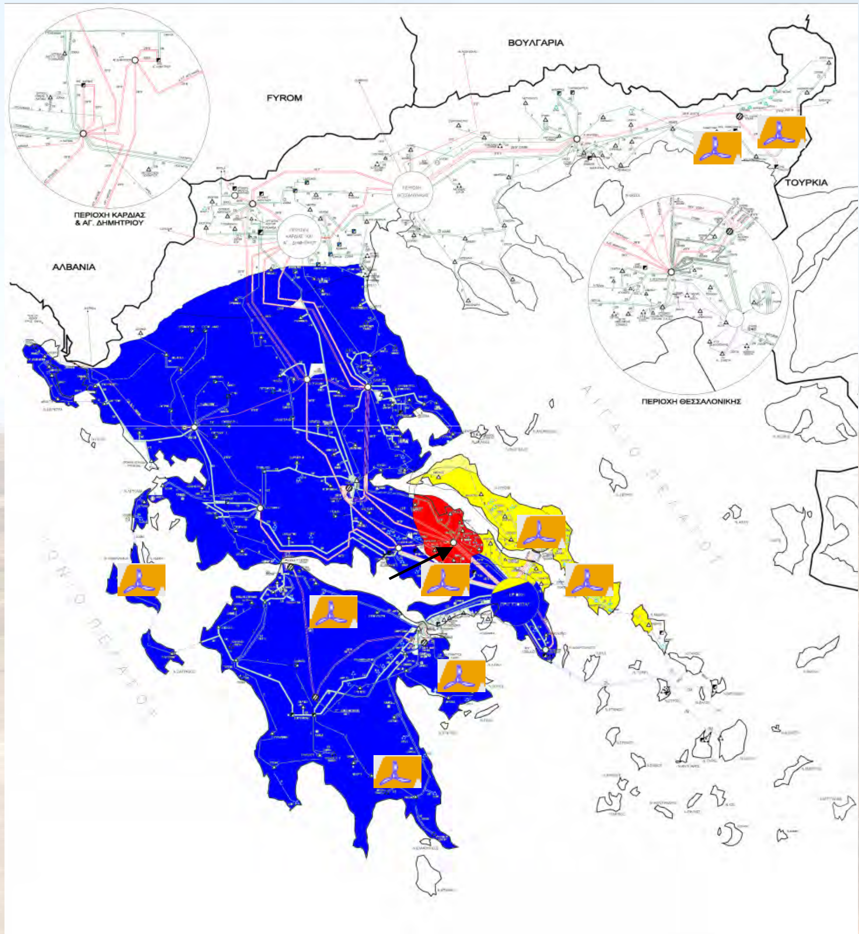
WTG behavior during Contingencies

- Under low penetration (current practice):

  WTGs tripped during faults leading to low voltages (e.g. u/v protection 0,8 pu for 80 msec)
- Large penetration:

  Need to keep WTGs in synchronism and to avoid losing large wind production
- WTGs must have fault ride-through capability i.e. to sustain in operation when very low voltages occur (during transients)
  - It is already required in several countries
  - Already available by the main constructors
  - Extremely crucial for system security

Three-phase short circuit in Larymna substation (150kV)



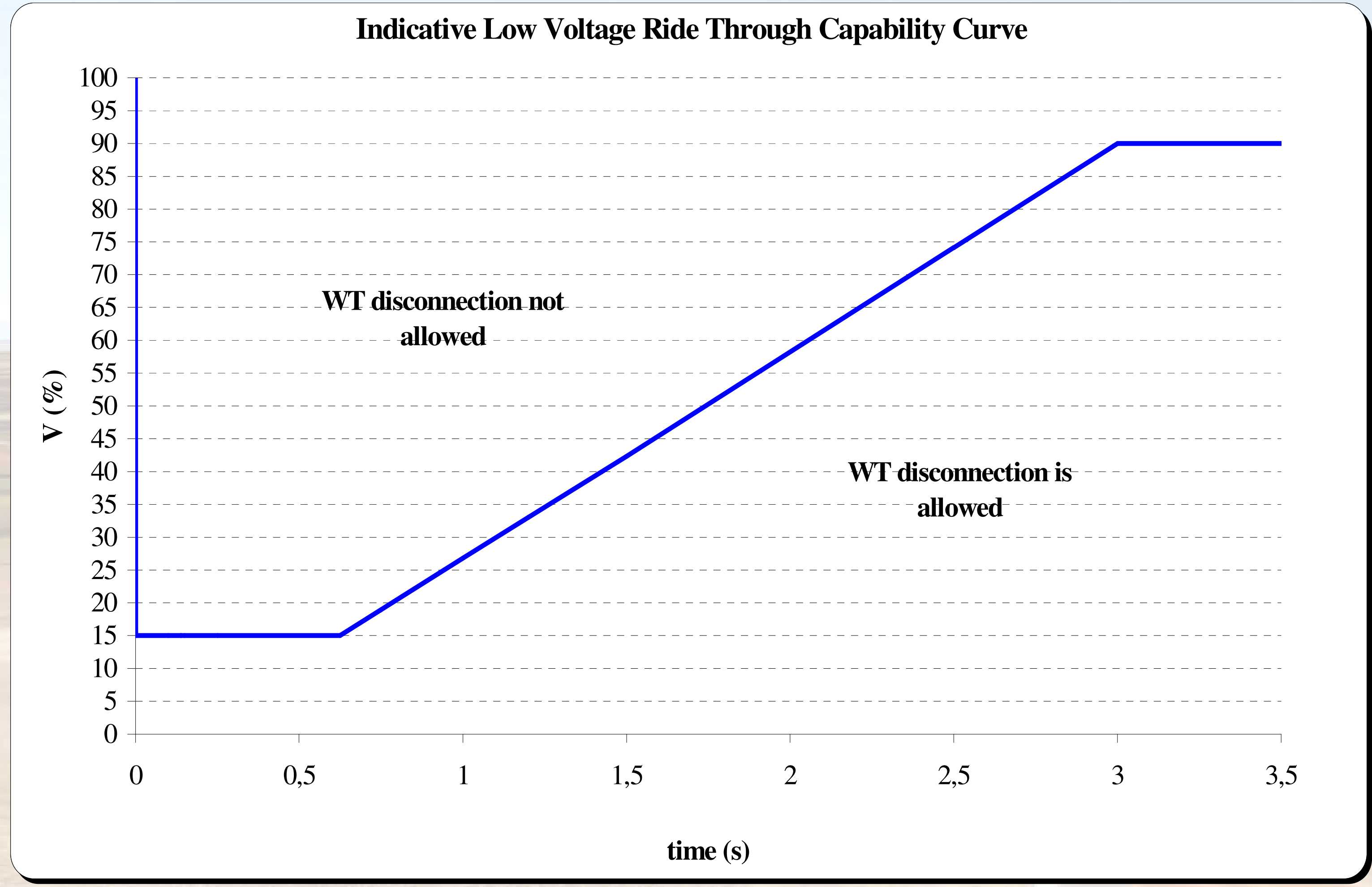
Red : $0<V<0.4$pu

Yellow : $0.4<V<0.6$pu

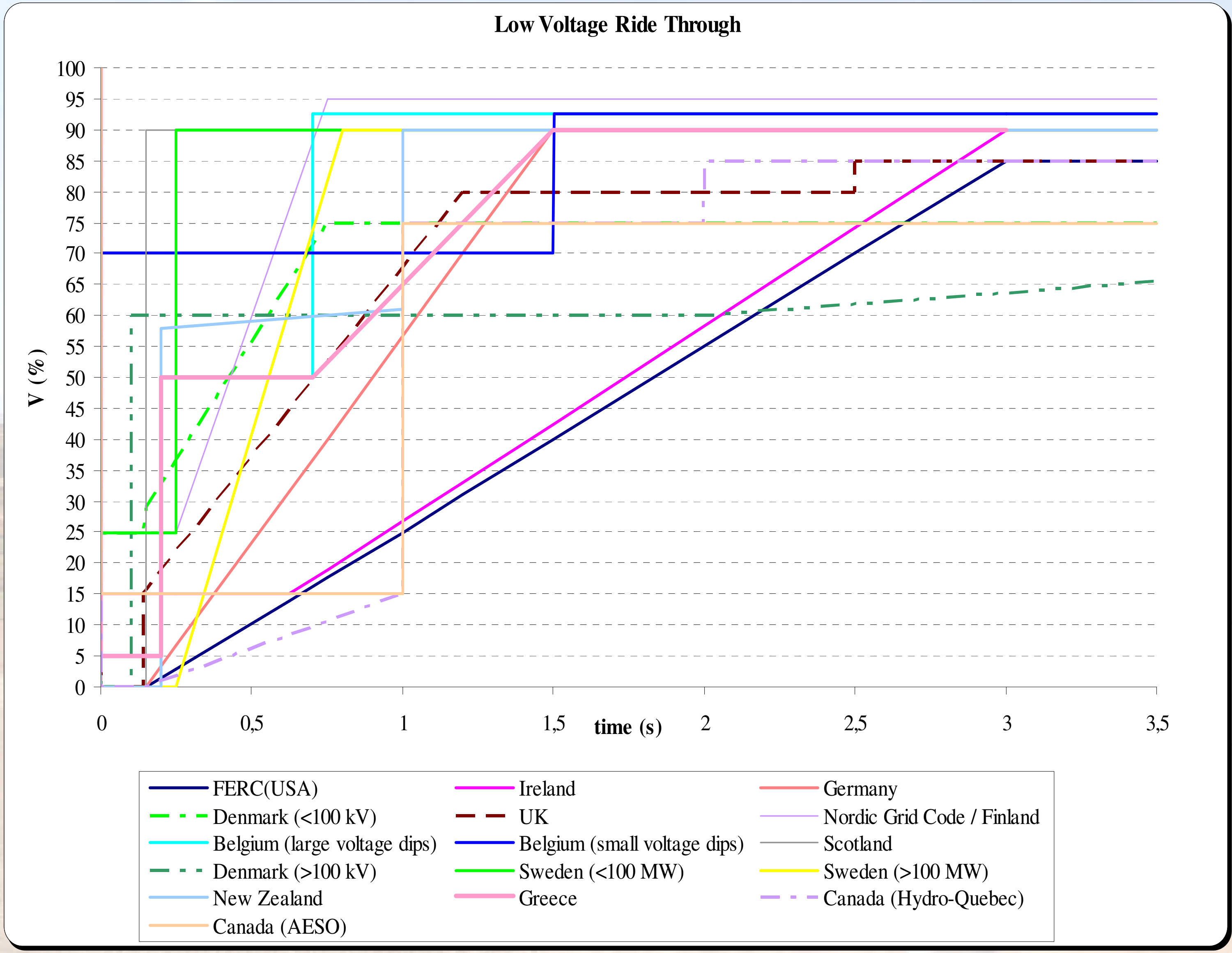
Blue : $0.6<V<0.8$pu

LVRT Definition

Requirement of Fault Ride-Through Capability during Voltage Drops in Transmission System



Comparison of LVRT Requirements



Proposed solutions

- Increase flexibility of conventional generators
- Storage options:
  - develop pump-storage hydros
  - use of electric cars
  - hydrogen economy (future option)
- Improve WTGs to achieve behavior “close” to conventional generators:
  - Contribution to frequency and voltage regulation
  - FRT capability
- Improved wind forecasts
- Increased spatial distribution during planning phase

Roadmap for Greece

Crucial issues

- Approval of WFs by local societies
- Increase of available transmission capacity
- Interconnection of Aegean islands
- Assessment of technical impact of large wind penetration and measures
- Impact on Electricity Markets and costs
- Wind prognosis
- Technical requirements for WFs

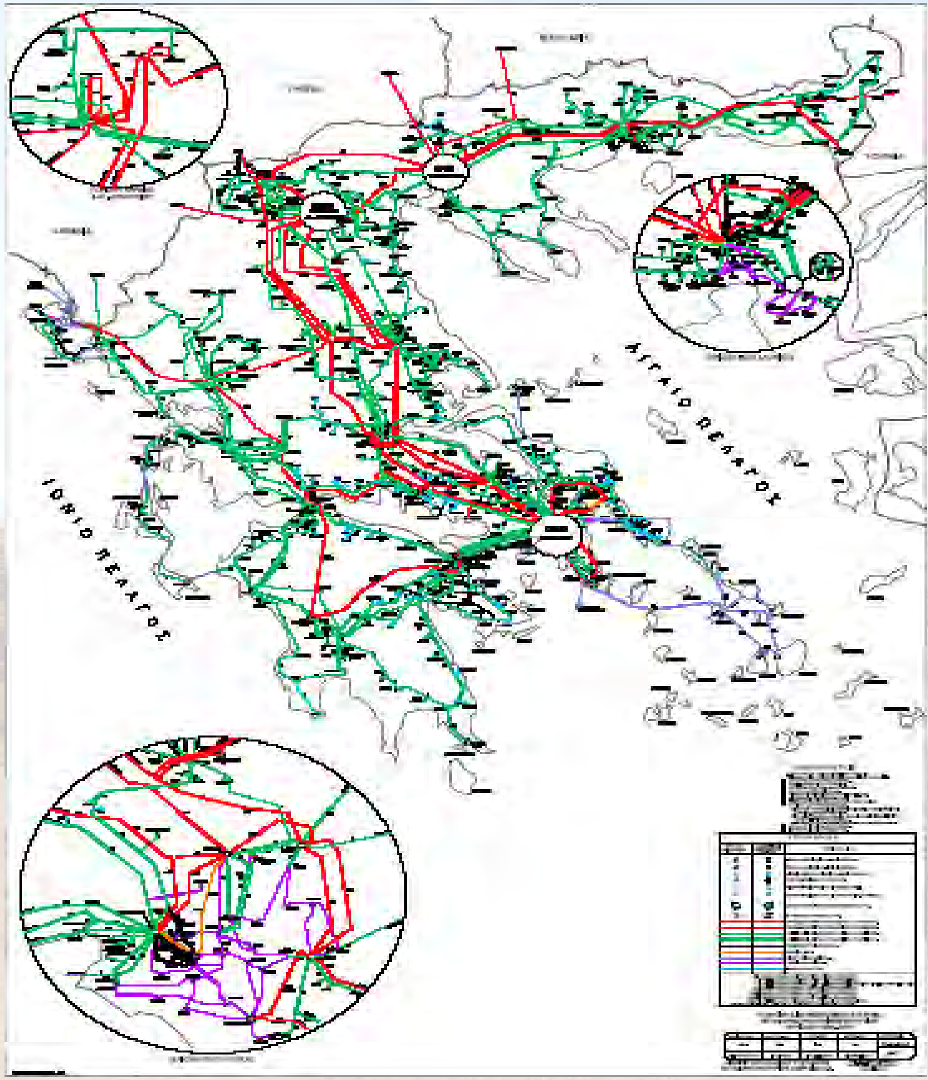
New Law for RES

- Calls for 40% RES contribution in electricity
- Simplifies and accelerates the licensing procedure
- Provisions for off-shore WFs
- Exploitation of wind potential of islands
- Expected to come in force within next weeks

HTSO estimates that 6-9 GW of wind capacity is needed to meet the target (depending on the load evolution and other RES development).

The official trajectory towards the target will be officially published on June

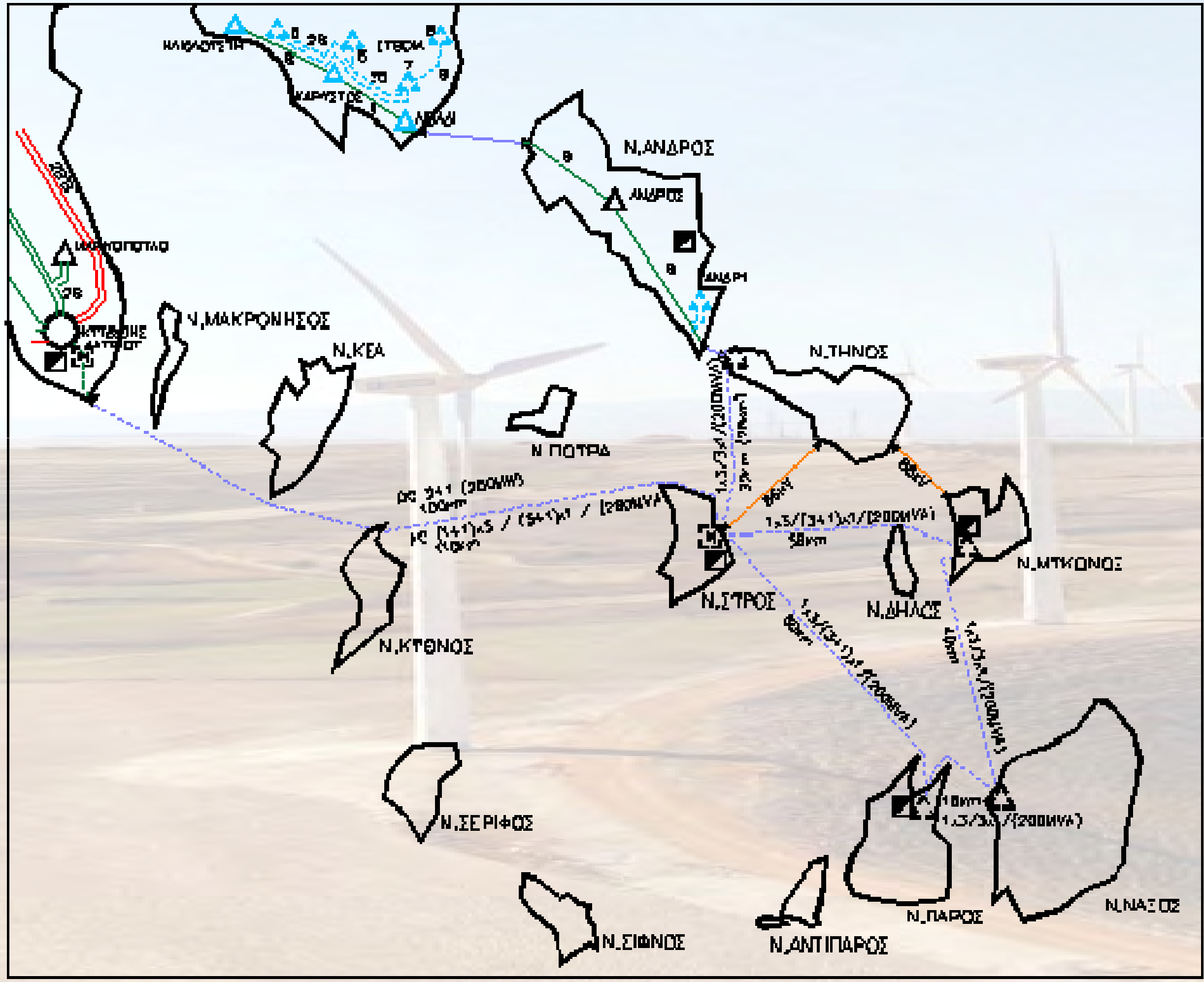
National Transmission Development Plan – Increase of available transmission capacity



Projects		
	Existing	Planned
150kV OHL (km)	11467	1000
400kV OHL (km)	4420	820
150kV S/S	284	130
400kV S/S	18	12
Cables 150kV (km)	267	120
Cables 400kV (km)	4	85

It is expected that after the realization of the planned projects at least 8.5 MW of wind power can be transmitted

Cycladic interconnection



- **Interconnection of Syros, Naxos, Mykonos, Paros with mainland through 150 kV cables of 250 km total length**
- **Capacity to connect 150- 200 MW**
- **Licensing has been completed**
- **Tender in public consultation**

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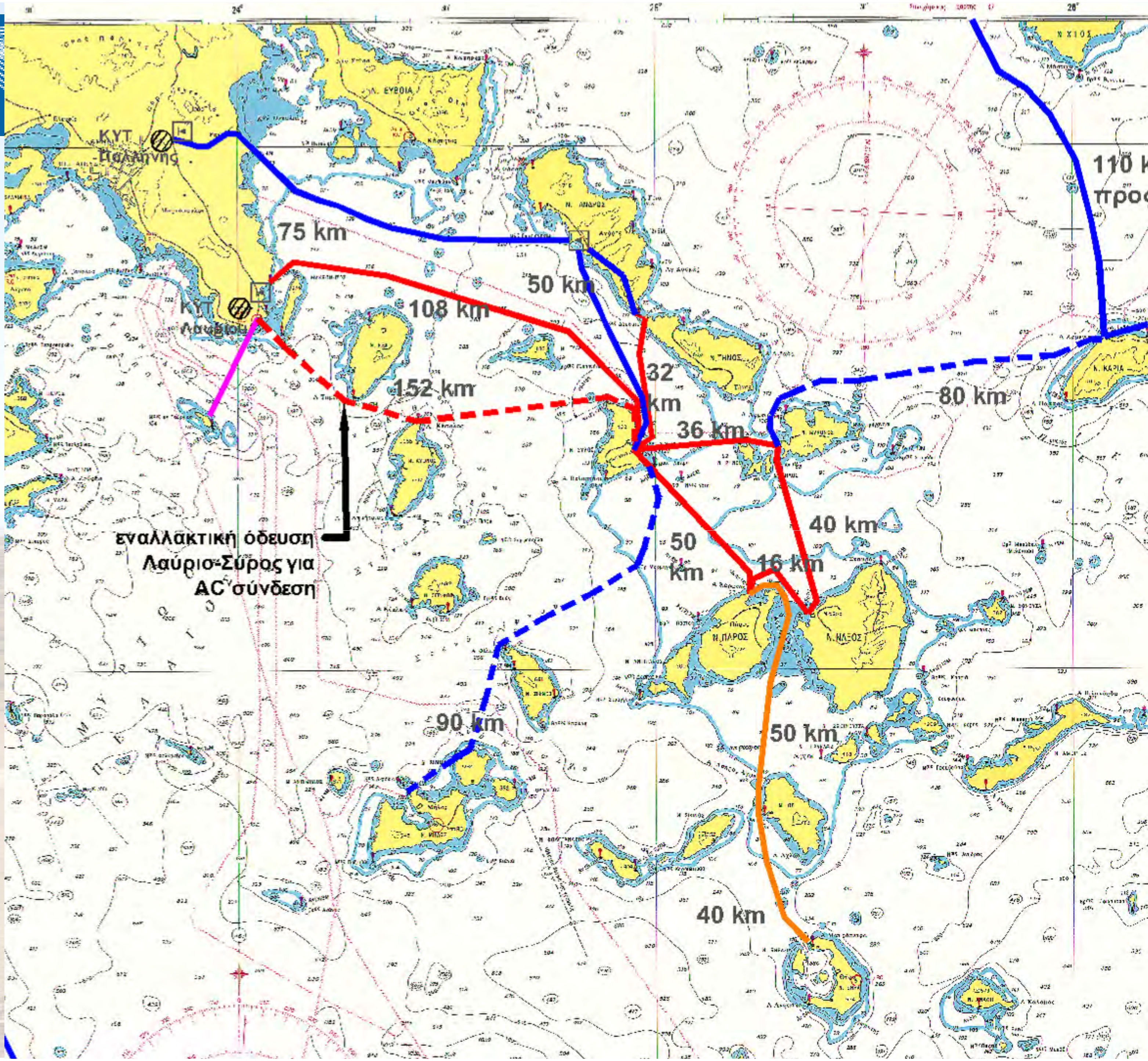
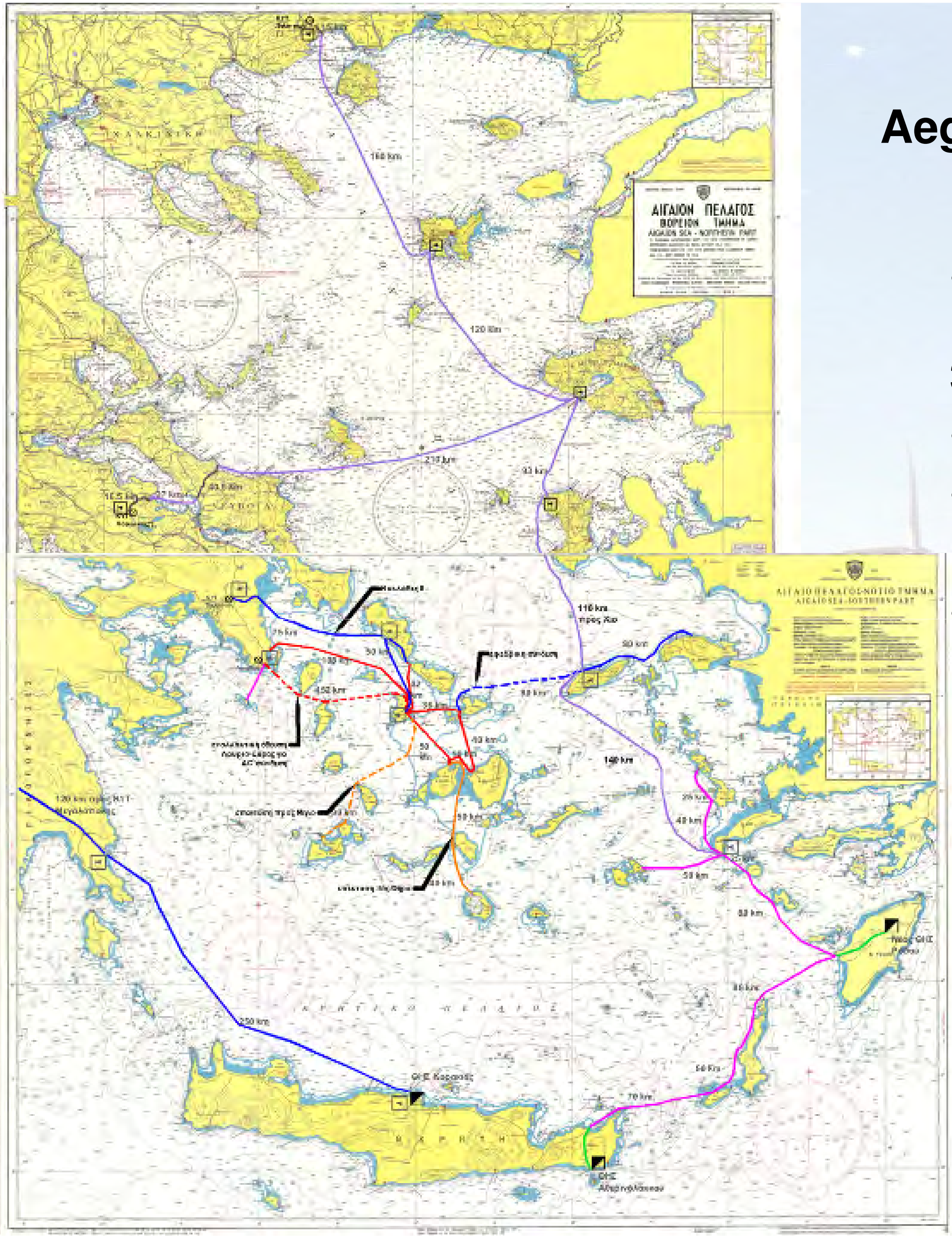


ΚΥΤ Παλλήνης
ΚΥΤ Λαυρίου
75 km
50 km
108 km
152 km
32 km
36 km
80 km
110 k
προς
40 km
50 km
16 km
50 km
90 km
40 km
εναλλακτική όδευση Λαύριο-Σύρος για AC σύνδεση



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Aegean interconnections
Long term plan

- Applications for production licenses on the islands 3.095MW, off-shore 3534 MW
- Preliminary studies on going
- Total length of undersea cables
  more than 1500 km
- DC or AC

Estimated total cost
3-4 bn Euros

Assessment of impacts

- Detailed studies have been launched to assess the increase of high wind penetration
- Impacts on the electricity market and costs
- Optimization of future generation mix to maximize wind power absorption
- Optimization of operation
- Estimation of wind power curtailments due to system constraints

Greek Grid Code future provisions for WTs

- Contribution to voltage regulation
- Contribution to frequency regulation
- Voltage support during system faults
- Wind Parks Communication interface (necessary signals exchanged with Dispatching Centers)
- Power quality requirements
- Certification and monitoring

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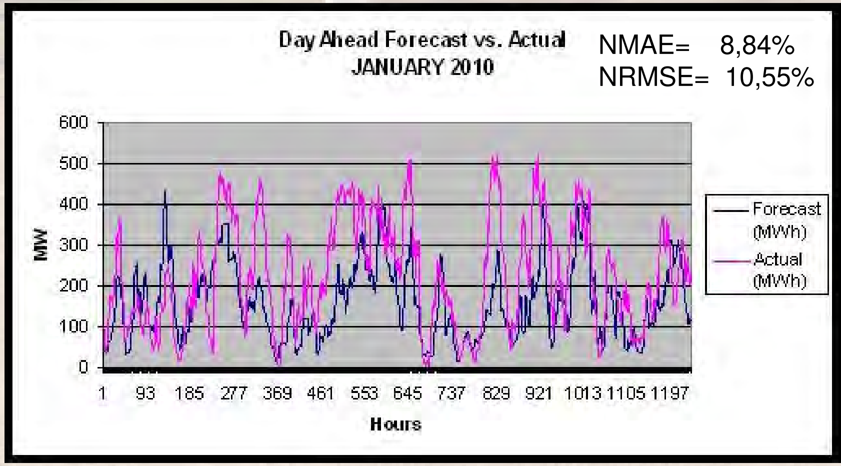
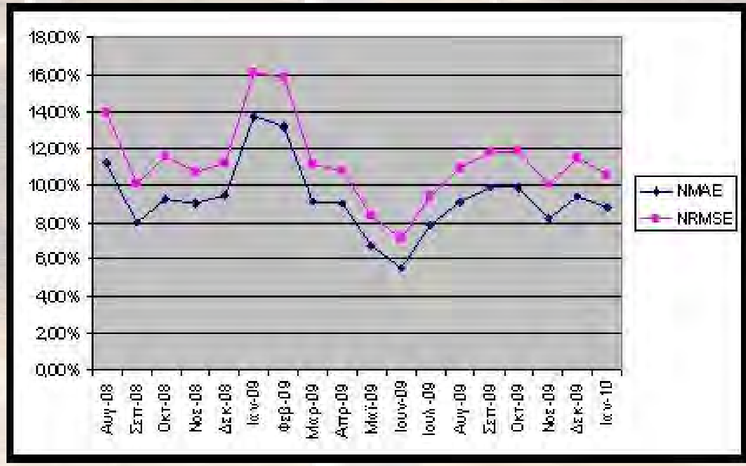
Wind Power Forecasting

- **Pilot application since August 2008**
- **Improvements and tuning of the model**
- **Based on Meteorological Forecast data and on on-site measurements**
- **Status : Tested/ tuned at Dispatching center**
- **Prediction : Good / Problems at high Production Hours**
- **To be integrated in the EMS procedures and tools**



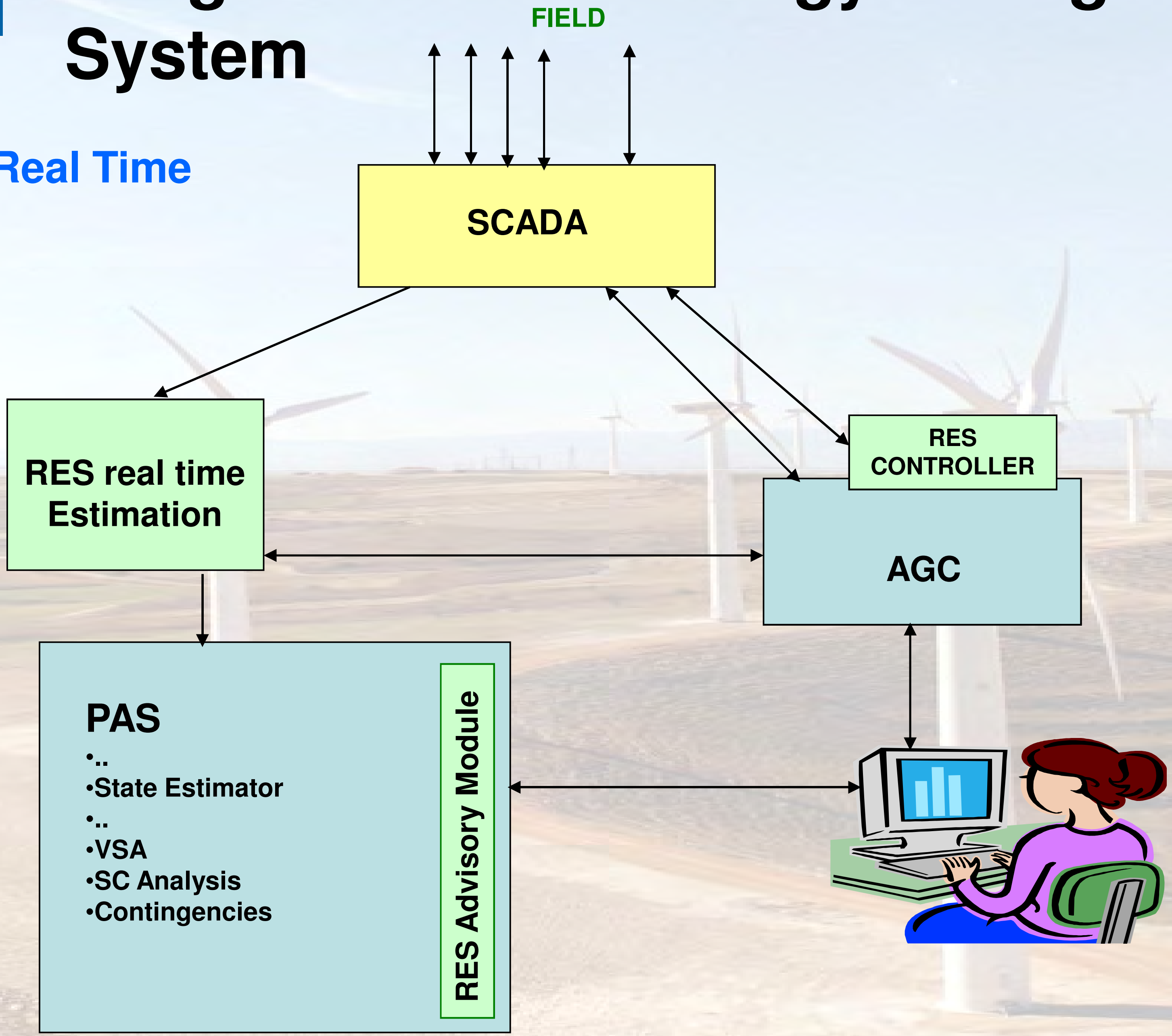


MONITORING & CONTROL

- Need for monitoring and control in real time – large amount of measurements
- High penetration may lead to curtailment of wind power under specific system conditions to ensure security
- Extended telecommunication infrastructure
- Bi-directional interface EMS – WF
- Extension of SCADA
- State estimation
- New S/W needed in EMSs , e.g. State Estimators
- Decentralized control-local CCs ?
- Market operation procedures, organization and tools

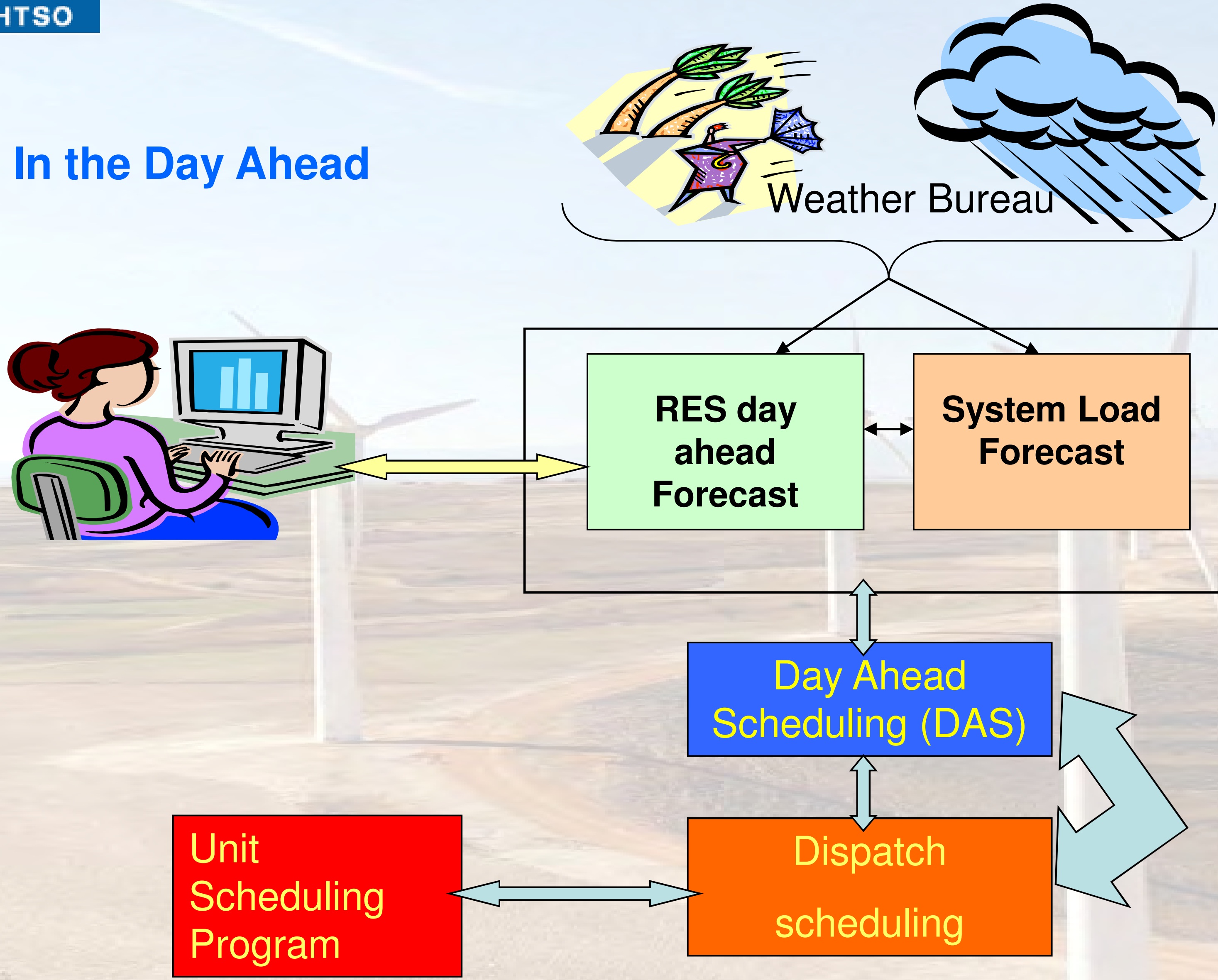
Integration in the Energy Management System

In the Real Time



Integration in the Market Procedures

In the Day Ahead



Activities for RES development in the Balkan Region

ENTSO-E area

ENTSO-E established on July 2009 under the provisions of the 3rd Energy Package

South Eastern Regional Group (CSE) of ENTSO-E

The EWIS project

- EC project to assess the transmission needs in Continental Europe to increase wind power
- 15 TSOs participated (ELIA, CEPS, ENERGINET, TRANSPOWER, AMPRION GmbH, 50Hz Transmission GmbHm, EirGrid, HTSO, National Grid, PSE-Operator, Red Electrica de Espana, Rede Electrica Nationalis, RTE , TenneT, Verbund)
- Specific reinforcements have been proposed
- Maximum and minimum load snapshots have been studied
- Balkan area has not been studied in detail
- Inadequate conclusions (only for Greece)
- Started at 5/2007 ended at 4/2010

Ten Year Network Development Plan for European Transmission System (TYNDP)

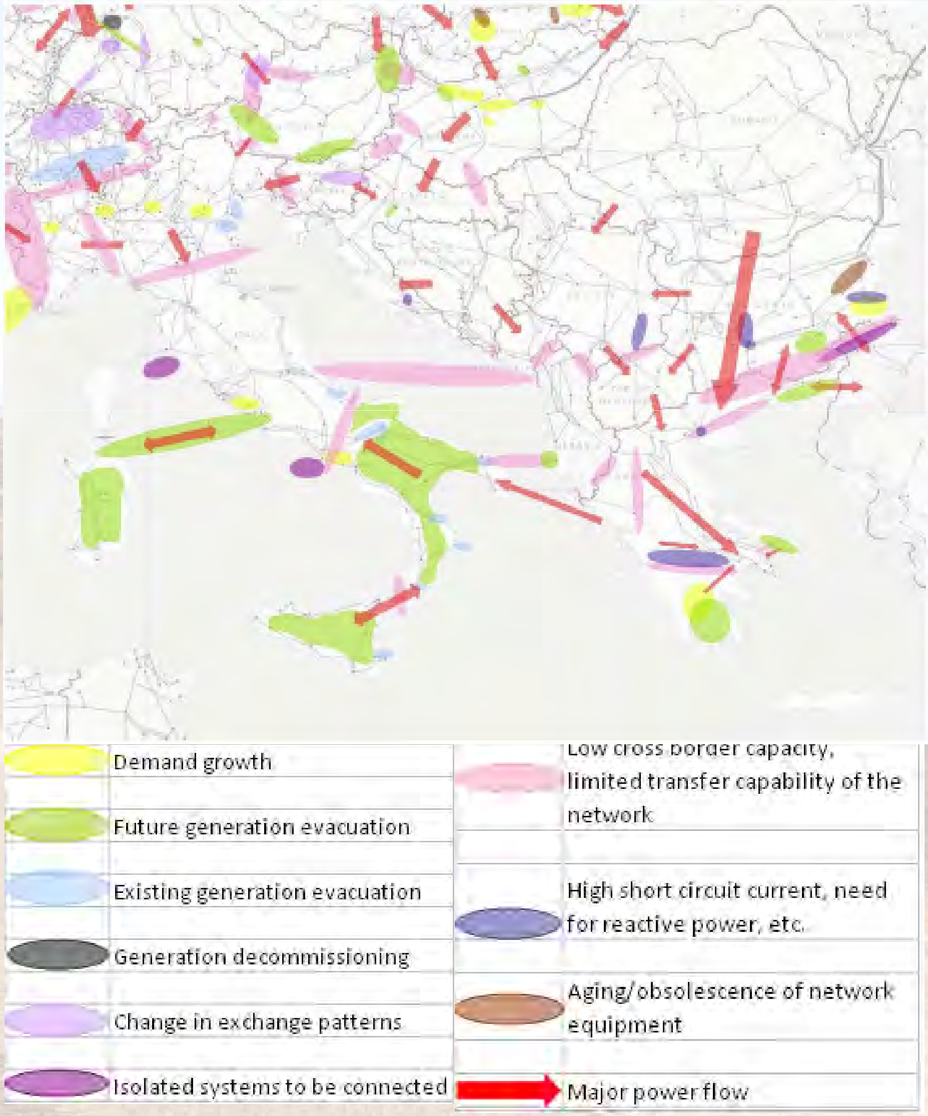
available on www.entsoe.eu

- 1st edition on June 2010 – Public consultation 1st – 20th April
- Projects of «European Interest » focusing on the interconnections

Main drivers :

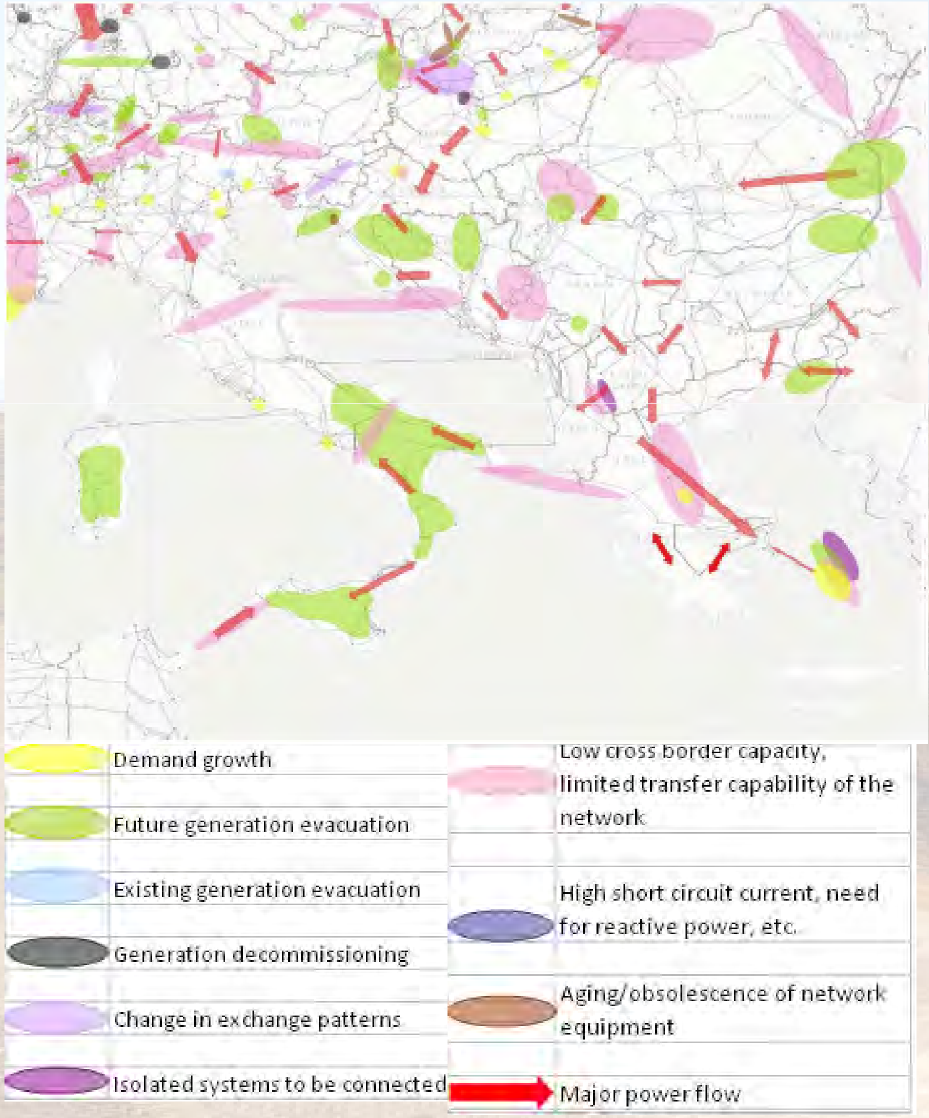
- Generation integration – especially RES
- Electricity market development
- Security of supply
- Increase interconectors' capacity

Grid reinforcement needs for Balkan systems up to 2015



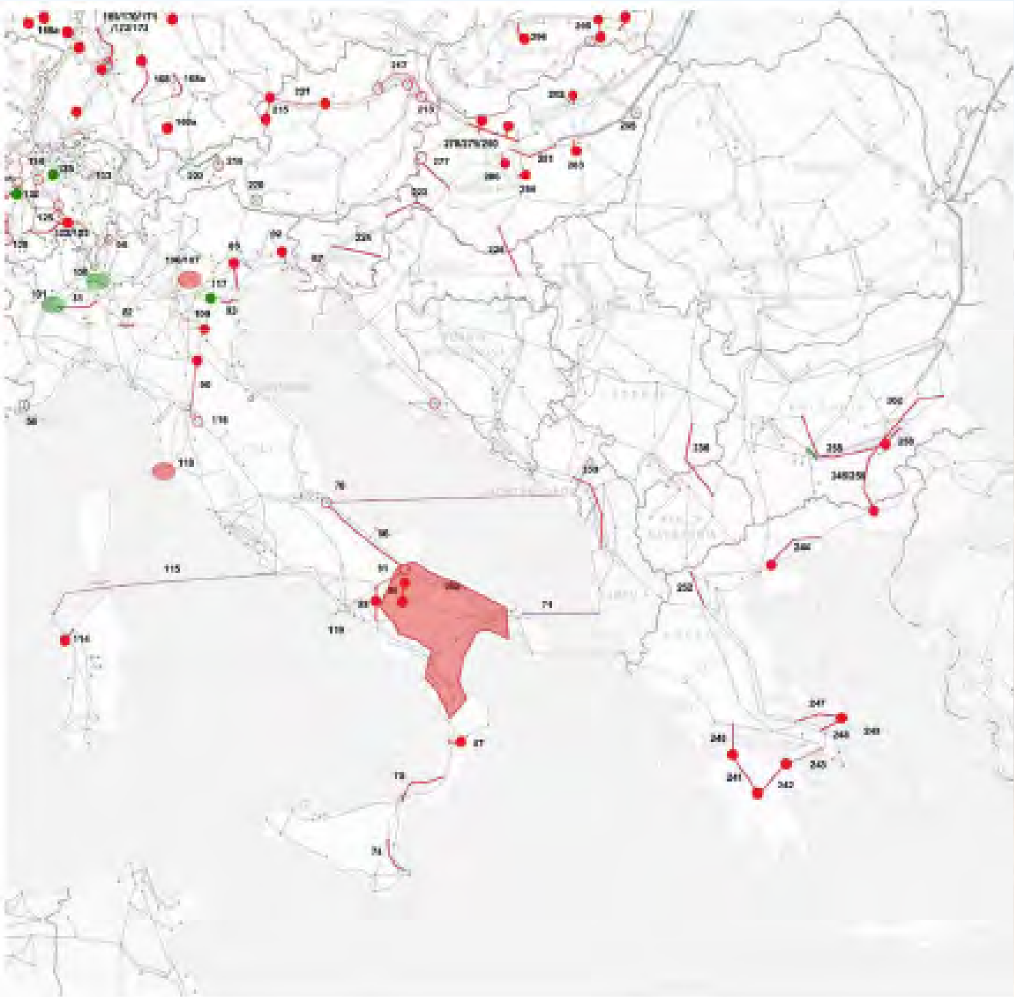
The most significant reinforcement projects for this period appear in Greece (Peloponnese, Thrace, Evia etc) and in south Italy.

Grid reinforcement needs for Balkan systems after 2015



Major reinforcement projects for this period appear also in other Balkan countries e.g. Bulgaria, Romania

New projects in Balkan up to 2015

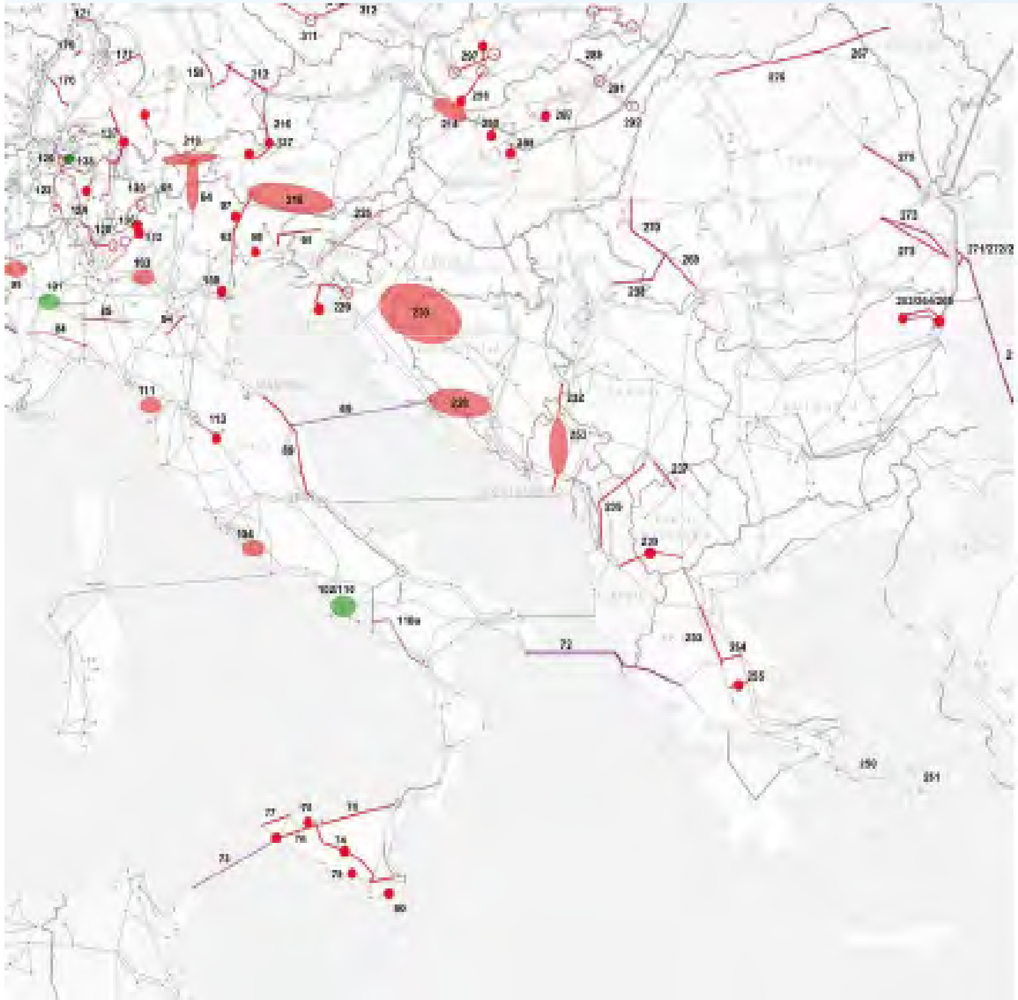


New important electric lines :

1) N. Santa (GR)-Maritsa (BG)
2) Ernestinovo (HR)-Pecs (HU)
3) Stip (MK) – Nis (RS)
4) Podgorica (ME)-Tirana (Al)
5) Italy-Montenegro (DC)
6) Italy-Albania (DC)

	AC 400 kV components
	AC 330 kV components
	AC 225 kV components
	AC 150 kV components
	AC < 150 kV components
	DC components

New projects in Balkan after 2015



	AC 400 kV components
	AC 330 kV components
	AC 225 kV components
	AC 150 kV components
	AC < 150 kV components
	DC components

New important electric lines :

1) Cirkovce (SI)- Heviz (Hu)
2) Pancevo (RS)-Resita(RO)
3) Okroglo(SI)- Udine(IT)
4) Italy – Greece new dc cable

Turkey connection

Through 3 400kV interconnection lines :

•Maritsa 3 – Hamitabat (line 1)

•Maritsa 3 – Hamitabat (line 2)

•N. Santa- Babaeski (line 3)

Studies:

•1st phase : static & dynamic

•2nd phase: dynamic performance tests and required improvements in TR (frequency control)

To start trial operation in 2010

ENTSO-E effort to establish common Requirements for Generators for Grid Connection and Access

- The requirements shall apply to all new Generating Units above a specific size.

These requirements can be classified as :

- General requirements that apply for all type of Power Generating Facilities connected to the Network
- Requirements for Synchronous Generator Units directly connected to the onshore Network
- Requirements for Power Park Modules, which are technologies not based on a synchronous generator directly connected to the Network (Wind Parks, Solar power stations etc)
- Requirements for offshore generators, includes all technologies connected to an offshore Network.

Common activities for large RES penetration in SE Europe

- Regular meetings for regional issues
- Regular information exchange for RES developments and prospects in each country
- Analysis of the current situation, regulatory and technical frameworks as well as the expected RES penetration in the area.
- Common studies have been launched to assess the impacts of the expected RES penetration in the Balkan grid.
- Detection of weak network points and proposals for reinforcements
- A coordinated Regional Transmission Plan will be issued on 2011
- Establish a regional “wind market”?

Conclusions

- Wind is the most promising source t meet the 3x20 targets
- Wind integration sets a series of technical challenges
- A roadmap to meet the targets for Grece has been set by the HTSO
- Regulatory changes in progress
- Major transmission projects have been planned
- Need for further studies and coordinated activities in the Balkan region
- ENTSO-E is a key player to commonly achiev the goals in a pan-European level.