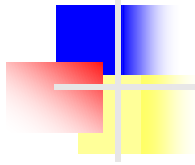# INTEGRATION OF RENEWABLE ENERGY SOURCES (RES) IN ROMANIAN POWER SYSTEM

- EVOLUTION, IMPACT AND CHALLENGES -

SOARE ALEXANDRU

Renewable Energy Development Development in Romania

- 3 MW was installed in Romania in 2006 year

- According to 77/2001 (EC) Directive and Romanian Energy Strategy for 2007 -2020 period it was elaborated 220/2008 law in the purpose to promote Renewable Energy System

- 28/2009 (EC) Directive established the Romanian quote at 24 % (2020) for Romania (quota for electrical energy produced)

- In 2016 year - there are 3023 MW wind power plant (1330MW –DO, 1693 MW – TSO) and 1340 MW solar power plant (1315 MW –DO, 25 MW –TSO)

- Tariverde Power Plant (600 MW), CEZ project, the second wind power plant in the world

- **Law purposes :**

1. Introducing the Renewable Energy Sources (RES) into the National Energy Balance

2. Decreasing the level of pollution (the level of NOx)

3. Assuring co-financiation necessary for obtaining external funds in order to develop Renewable Energy Sources in Romania, in the limit of yearly national budget

4. Defining the RES types which are to be sustained: hydro-power plants with installed power less than 10 MW, wind and solar power plants, geothermal energy, biomass, bio-liquids, landfill gas, sludge fermentation gas in waste water treatment plants

Capacity installed in Romania function of primary sources, 2016

**Primary Energy Sources in Romanian Electrical National System**
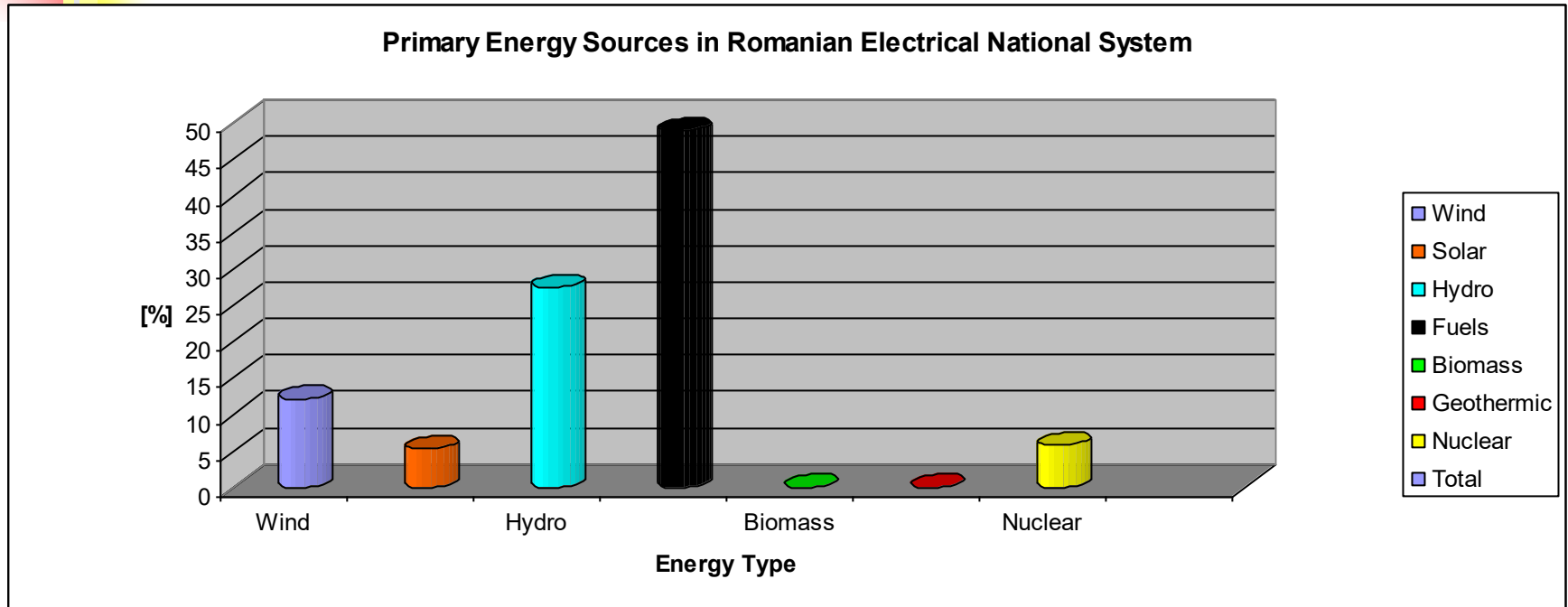
- Integrating high amount of RES in Electrical National System, with an important participation to production (in present over 20% from total production)
- The RES power plant participation to system stability and safety is reduced comparative with classical power plants

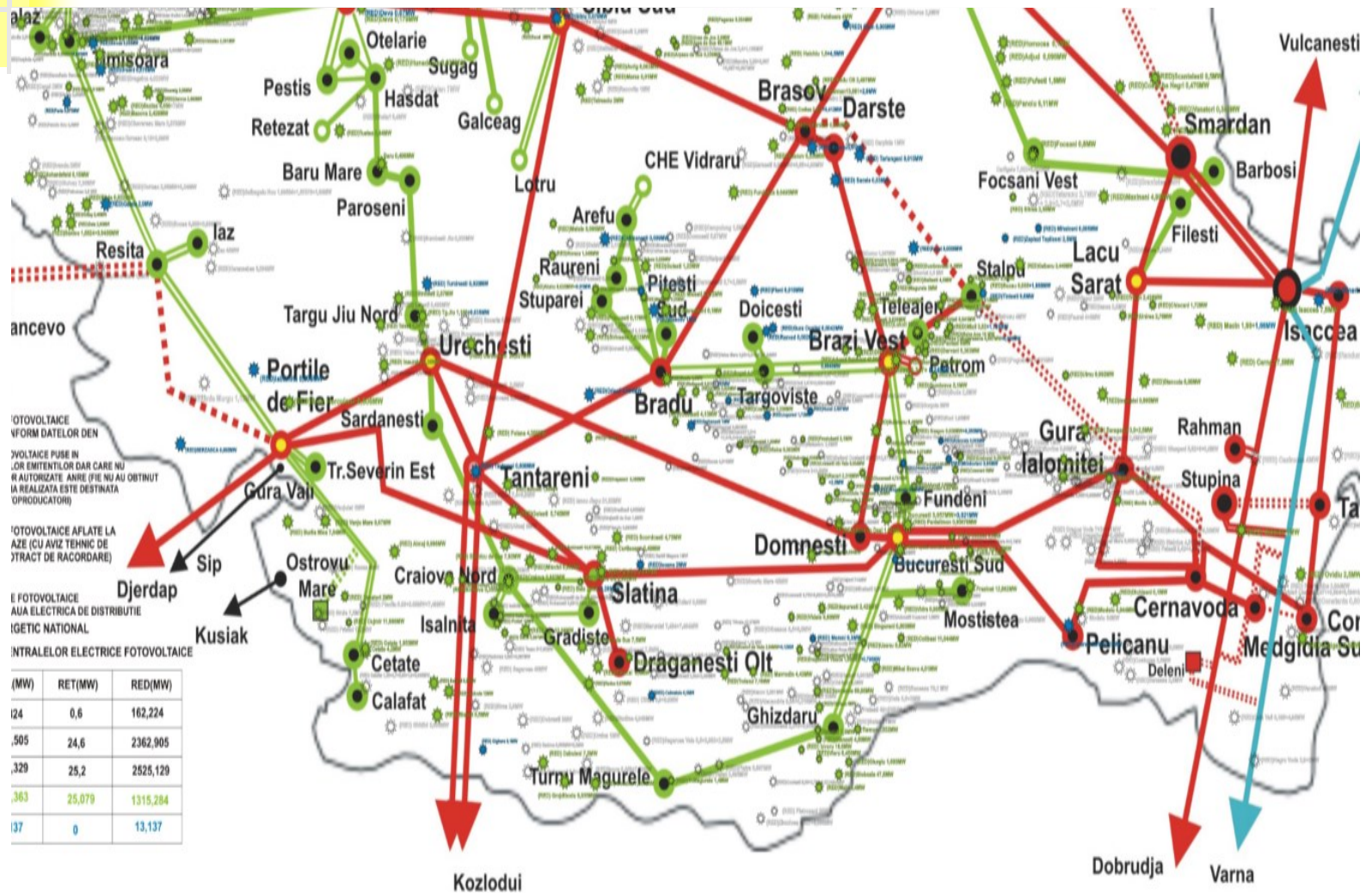# Wind power plants in Romania
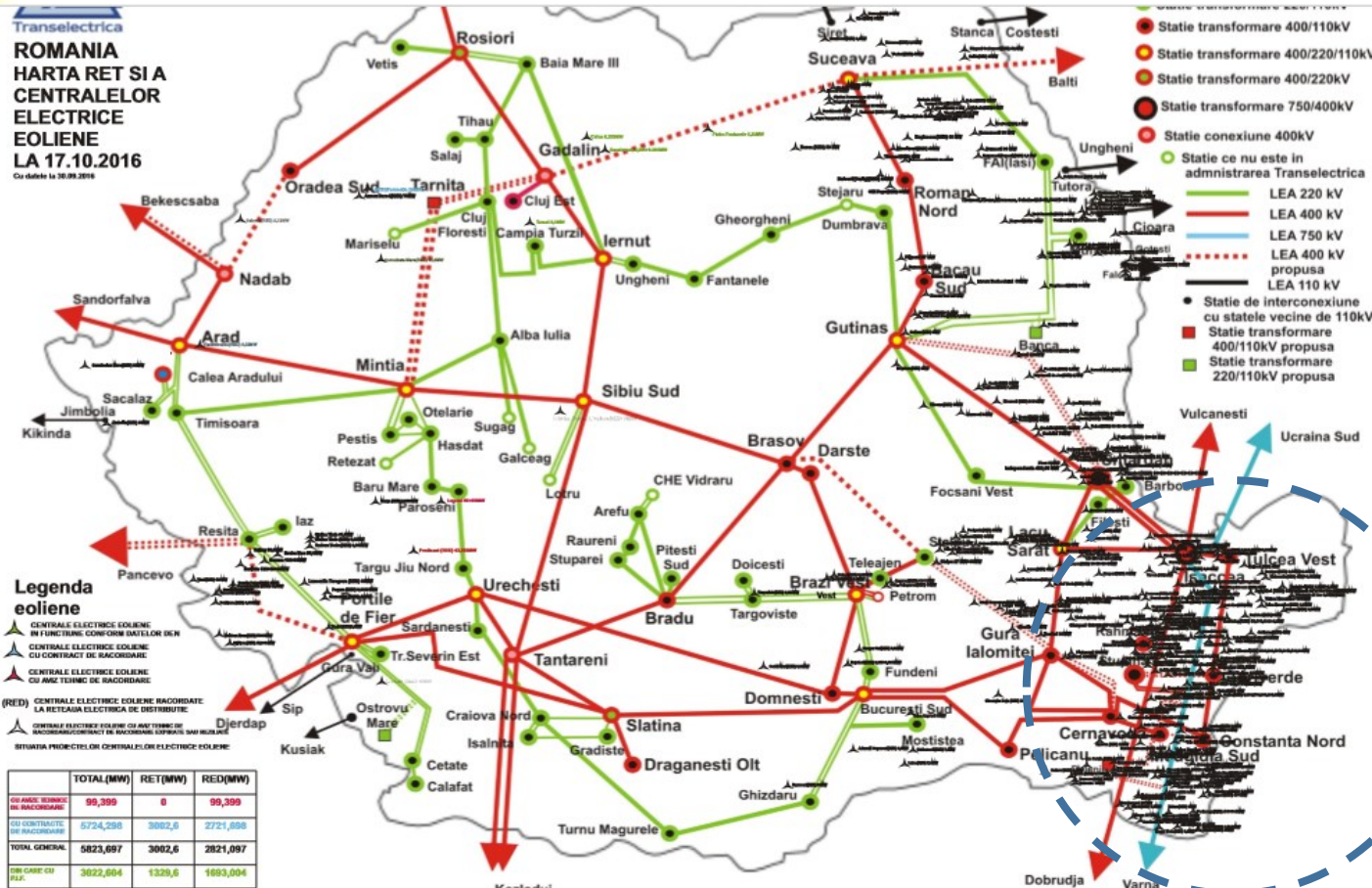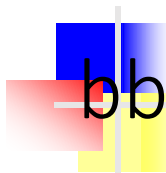
Solar radiation map - România
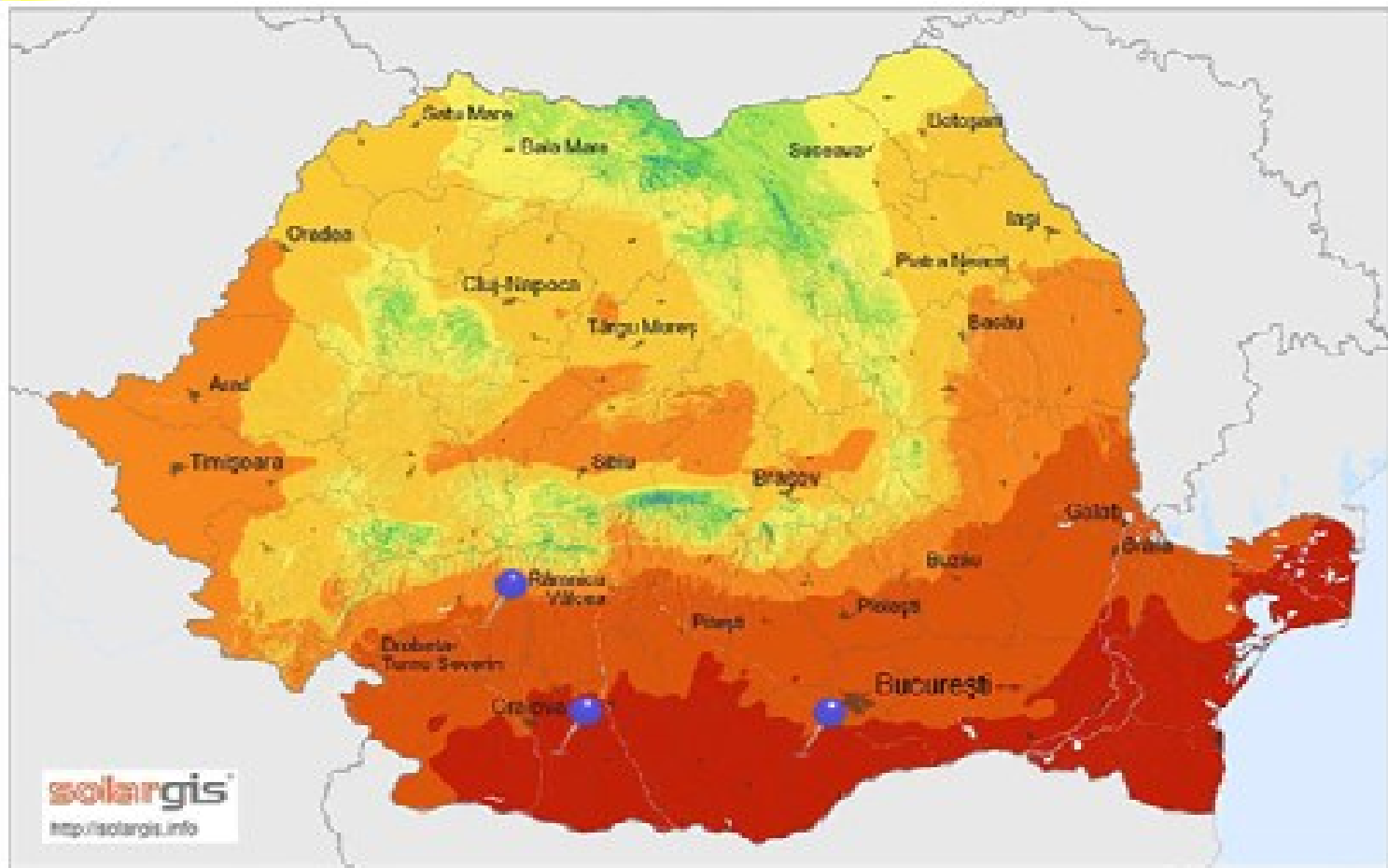
1400 kWh/m2

Solar power plants in Romania

Changes necessary in legislation

- Technical Norm *Connecting Wind power plant at public electrical networks* (51/2009 ANRE order) with correction;

- Technical Norm *Connecting Photovoltaic power plant at public electrical networks* - Technical condition (30/2013 ANRE order)

- Operational Procedure *concerning Putting In Function (PIF) for test period and certification of wind and solar plant (74/2013 ANRE order)* with correction.

- Operational Procedure concerning *evaluation of power produced by wind and solar plant which can be introduced in national system in safety conditions (4/2013 ANRE acceptance)*

- According to 51/2009 and 30/2013 order was established the level for RES power plants dispatching : > 5 MW. Till the existence of RES PP, the level was 10MW for hydro units, 20 MW for thermoelectric units.

- It was established RES specific conditions like: frequency characteristic, Fault Ride Through (FRT) protection, obligation for RES power plant to have a generation evaluation (generation forecast) and send it to analyze departments within DO/OTS (for power systems scheduling operations)
- It was established technical criteria function of power level, starting with a small number of requirements (for small power plants) and finishing with complete requirements (for big power plants).
- The power levels was fixed between (0MW,0,4MW], (0.4MW;1MW], (1MW;5MW], (5MW;10 MW], 10 MW and more.
- It was established a coordination between the 8 DOs and TSO concerning the connection process (function of power level, data communication etc).

Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code (elaborated by ENTSO-E) on requirements for grid connection of generators

Regulation no 631/2016 was elaborated for harmonization requirements in generators connecting process, at the UE level (all generator types) : power module, power modules from power plants and synchronous generators.
All UE countries has to take into consideration security of energy supply for a interconnected internal energy market.

Network development for RES integrating

- New 110 kV, 220 kV and 400 kV OHL

- Increasing the transformers power

- 110 kV OHL upgrading

- Developing of EMS SCADA (OTS SCADA) and DMS SCADA (DO SCADA)

- Introducing of 1phase and 3phase automatic reclosure on 110 kV OHL

- Developing the TSO monitoring system of energy electrical quality

- It was improved protection systems of substations near to RES s/s

- New interconnections projects

Transelectrica is elaborating 10 years Network Development Plan (TYNPD) taking into account assurance for a proper adequacy of national power system evolution:

Criteria considered : major changes in power load flow, connecting to the network of new power plants (wind and solar PP - 4363 MW), demand evolution for cross-border exchanges to assure a proper functioning of internal energy market etc.

Solution selection it is done using cost-benefit analysis (technical end economical indicators)

Methodologies/Analyses used for elaborating TYNDP require next steps: electrical energy prognosis for Romanian system; the active/reactive power prognosis at specific moments (maximum/minimum demand in winter/summer) for each s/s; import/export energy transit and electrical energy prognosis, active/reactive power balances at specific moments, operating regimes analyses for reference period (power losses, voltage stability in network nodes, small perturbation and transitory stability).

System analyses and **necessary calculations** elaboration required model calculation which correspond to the following characteristic situations (Year0+1, Year 0+5, Year 0+10)

1)**NETWORK BASE MEDIUM REGIMES** – common regimes
2)**NETWORK DESIGN REGIMES** – the hard regimes (i.e. maximum generation, maximum load demand)

The analyze of network dimensioning for study time intervals is realized by PE 026/1992 Norm. This norm does not include how is foreseen wind/solar PP generation.

It was necessary additional hypothesis:

- **for NETWORK BASE MEDIUM REGIMES:** Generating power is considered 30% for RES (this threshold will be changed after collecting of relevant information from the installed RES)
- **for NETWORK DESIGN REGIMES**

It will be respected the rules in area where will be installed the new RES

- *In winter evening/ summer morning maximum (power curve)*

a) The new RES generated power will be considered at 100% $P_{instaled}$ in the N/N-1 regime.

b) The rest of RES power is considered 70% $P_{installed}$

c) The biggest thermoelectric units is considered at 100% $P_{installed}$
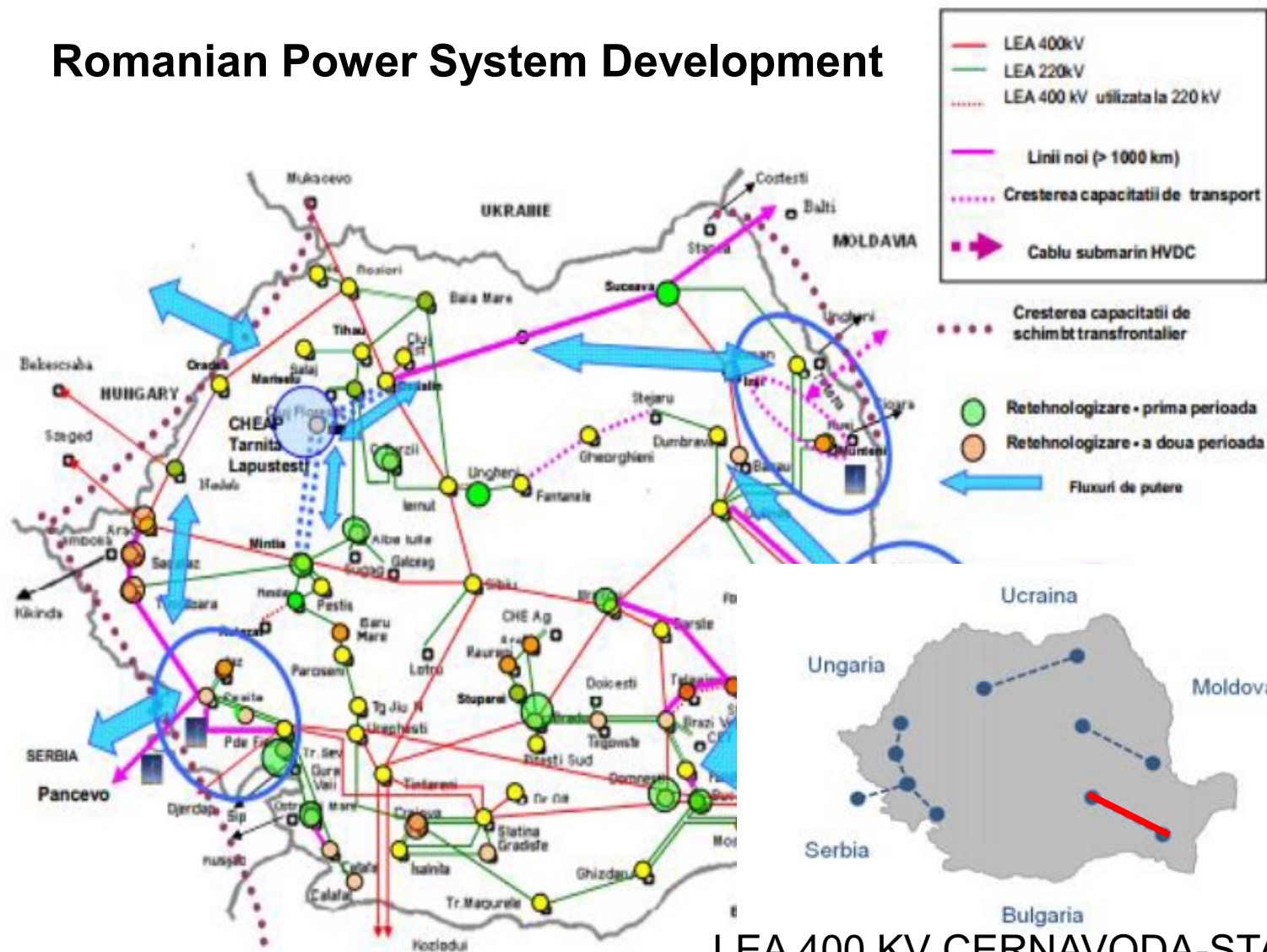
d) Nuclear and Hydro PP power is 100% $P_{installed}$

- ***In summer night minimum (power curve)***

a) The new RES generated power will be considered at 70% $P_{instaled}$

b) The biggest thermoelectric units is considered at 70% $P_{installed}$

c) Nuclear PP – 100%, Hydro PP -50 % $P_{installed}$

Romanian Power System Development
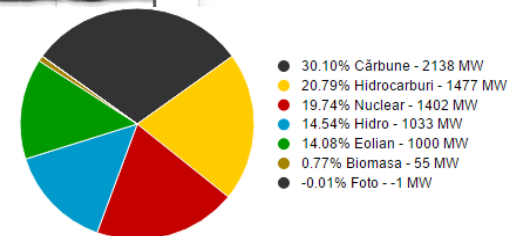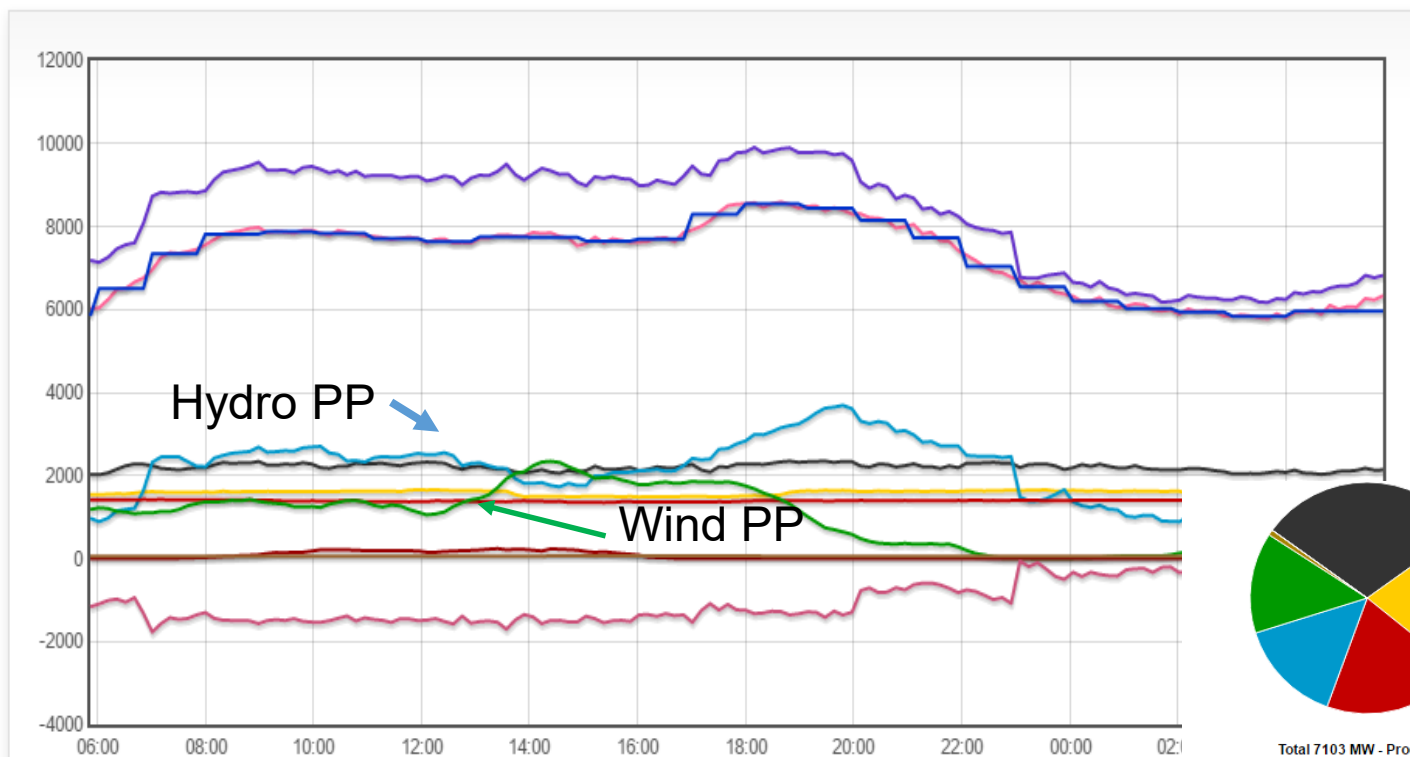

LEA 400 KV CERNAVODA-STALPU

Impacts on reserve capacity and balancing marke

- RES generation is very fluctuant (at the *increasing* and *decreasing* too), regarding the peak value and time gradient ($\Delta P/\Delta t$), with 1000 MW/h variation time, both at maximum and the minimum load time moments;

- RES generation increase, promoted by the support scheme- lead to minimize system reserves offered by classical generating units. Example: a large number of classical generating units are obliged to operate at minimum level, to be stopped or to be preserved. Therefore important reserve capacity (primary, secondary slow and fast tertiary reserves) are not available in critical moments.

- Big groups like Turceni, Rovinari (330 MW) reduce their operation time due to RES production. Therefore, the benefit of owner grows down. Classical generating units, like thermoelectric units (fuel oil and lignite too), was affected due to high operating (maintenance) COSTS. It was noticed incapacity to respect pollution criteria and impossibility to refurbish such kind of units.

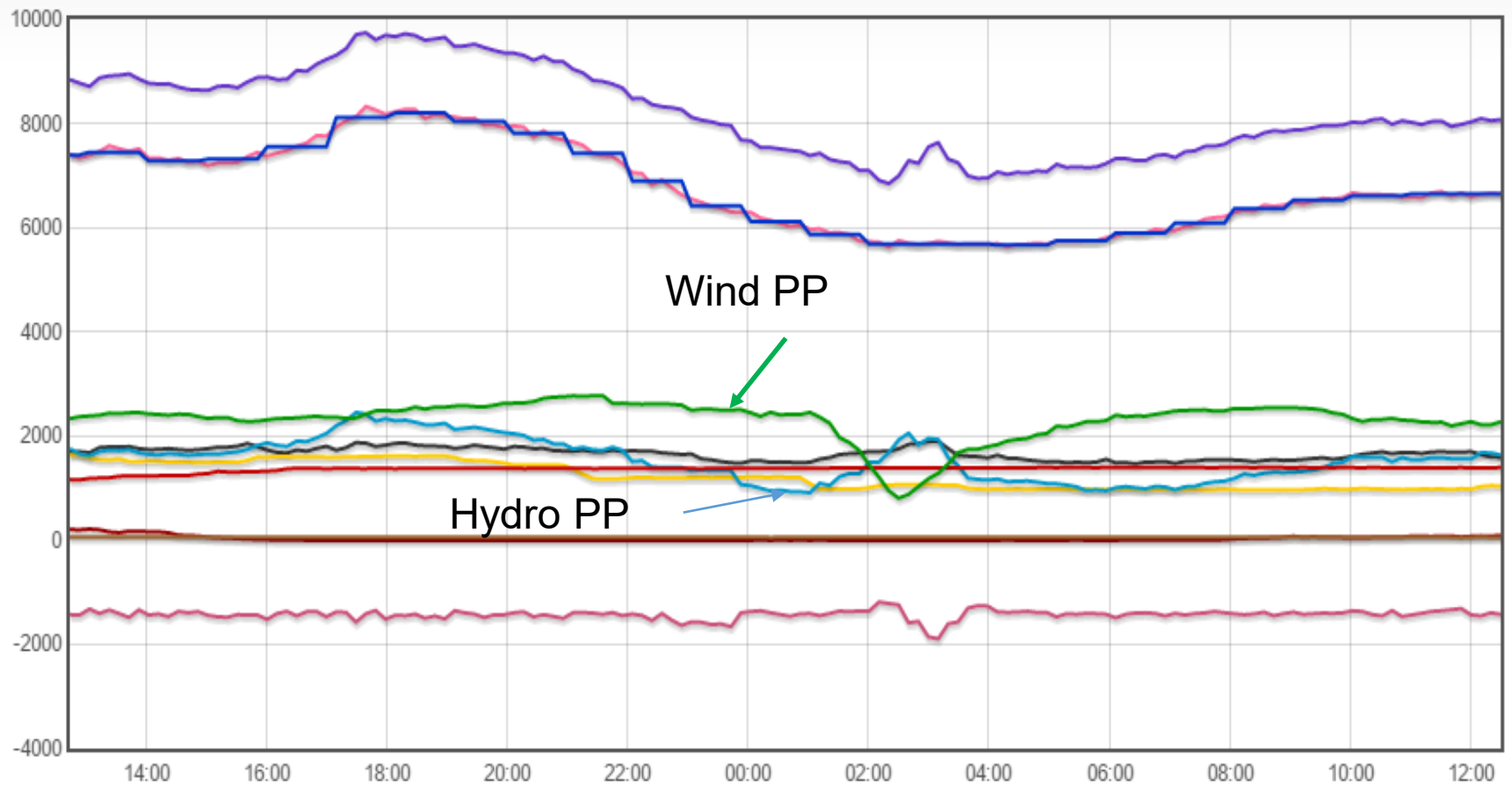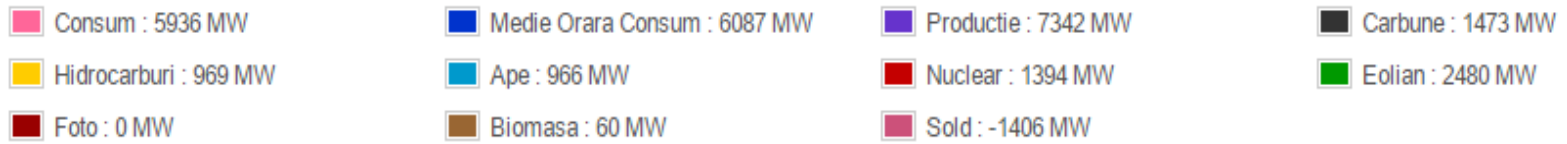# Production and load demand curve, 7-8 November 2016

Consum : 7633 MW — Medie Orara Consum : 7698 MW — Productie : 9012 MW — Carbune : 2183 MW
Hidrocarburi : 1486 MW — Ape : 2113 MW — Nuclear : 1360 MW — Eolian : 1807 MW
Foto : 4 MW — Biomasa : 59 MW — Sold : -1379 MW

Hydro PP

Wind PP

30.10% Cărbune - 2138 MW
20.79% Hidrocarburi - 1477 MW
19.74% Nuclear - 1402 MW
14.54% Hidro - 1033 MW
14.08% Eolian - 1000 MW
0.77% Biomasa - 55 MW
-0.01% Foto - -1 MW

Total 7103 MW - Productia in 08-11-2016 ora 06:02:45

12-13, November 2016

Consum : 5936 MW   Medie Orara Consum : 6087 MW   Productie : 7342 MW   Carbune : 1473 MW

Hidrocarburi : 969 MW   Ape : 966 MW   Nuclear : 1394 MW   Eolian : 2480 MW

Foto : 0 MW   Biomasa : 60 MW   Sold : -1406 MW

Wind PP

Hydro PP

12-13, February 2016

- **Example 2016 winter (January and February month), with very low temperatures(-20°C) and load demand increased (10 GW including exchanges with neighbor networks)** *combined with small production from RES power plants*. It was necessary an additional purchase (fuel oil) for slow tertiary reserves .

- The effects combined of dry periods (reduced energy and reserves from hydro-power) with reduced RES generation (wind power plants) requires additional reserves.

- The RES unpredictable generation and load variation lead to INCREASE the reserve capacity in the system and the COST of system balancing

- For assuring a proper operation of national power system, was introduced additional scenarios operation 1) **Smax from RES (4363 MW)** and 2) **Smin from RES = 0 MW**, increasing the effort for stability assessment (steady-state and transitory)

Ancillary Services

Primary Reserve – *has to be automat and full mobilized in maximum 30s, at $\pm$ 200 mHz frequency deviation from reference value and has to remain active minimum 15 minutes if frequency deviation persist.*

Secondary Reserve - *has to be automat and full mobilized in maximum 15 minutes, at frequency deviation from reference value.*

Fast Tertiary Reserve – *his purpose is to assure replacement (15 minutes) of secondary reserve*

Slow Tertiary Reserve – *it is assured at National Dispatch command, characterized by starting time less than 7 hours*

- Reserve capacities in Romania are mainly hydro units and thermoelectric units (inferior carbon -lignite, fuel oil and gas units)

- Generating units are qualified by specific procedures in order to supply ancillary services

Regulated component = a certain (fixed quantities) reserve supply by a balancing responsible side, at regulated tariff
Competitive component = it is obtained in a competitive way (auctions)

| YEAR	ACHISITION TYPE	SECONDARY RESERVE	FAST TERTIARY RESERVE	SLOW TERTIARY RESERVE
2013	REGULATD COMPONENT Contracted quantity [h*MW]	3,121,380	6,307,200	4,267,144
	COMPETITIVE COMPONENT Contracted quantity [h*MW]	45,940	0	1,007,650
	TOTAL	3,167,320	6,307,200	5,274,794
2014	REGULATD COMPONENT Contracted quantity [h*MW]	1,662,940	700,800	6,465,380
	COMPETITIVE COMPONENT Contracted quantity [h*MW]	1,945,010	5,091,691	0
	TOTAL	3,607,950	5,792,491	6,465,380
2015	REGULATD COMPONENT Contracted quantity [h*MW]	767,310	480,890	6,304,000
	COMPETITIVE COMPONENT Contracted quantity [h*MW]	3,136,625	5,662,030	1,054,320
	TOTAL	3,903,035	6,142,920	7,358,320

-The RES generation increase leads to significant differences in load-generation Balance.
 -Medium values for the year 2015 : 254,74 lei/MWh (deficit price), 4.7% increase than 2014 year and 15.89 lei/MWh (excedent price) 48.4% decrease than 2014 year.
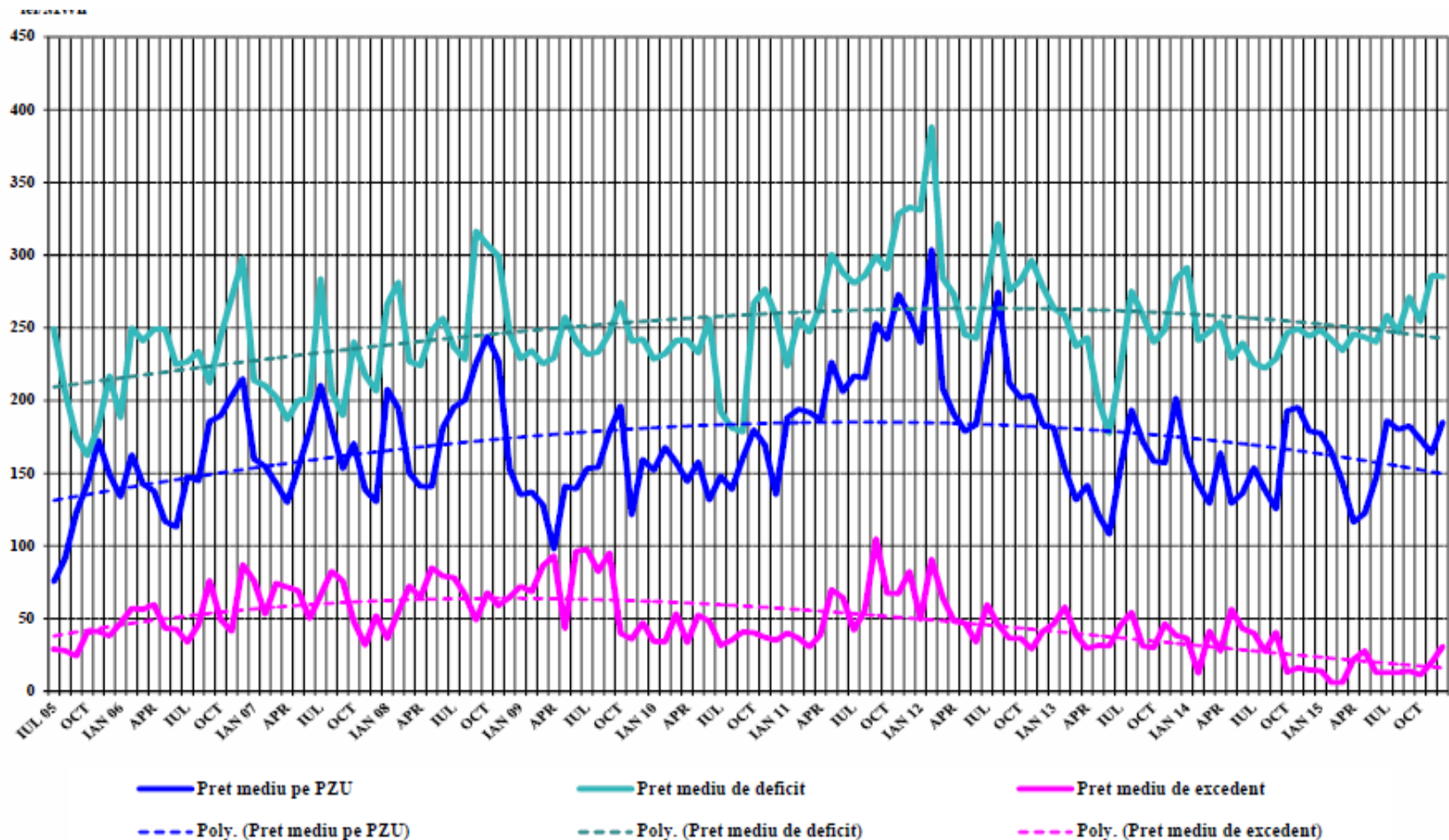
1 MW Storage system within Cobadin Wind Park -26 MW
0.5 MW Storage system within Mireasa Wind Park-50 MW

- Using Storage Systems are a possible solution in a advanced implementation of RES, to avoid unpredictable behavior

- There are projects for a pumped hydro-storage (1000 MW) at Tarnita-Lapuseni (uncertain)

- It will be PIF first Battery Energy System Storage (BESS) into a Romanian wind power plant In November 2016 (EDP Renewables will operate the battery for improving the wind PP behavior on the energy market)
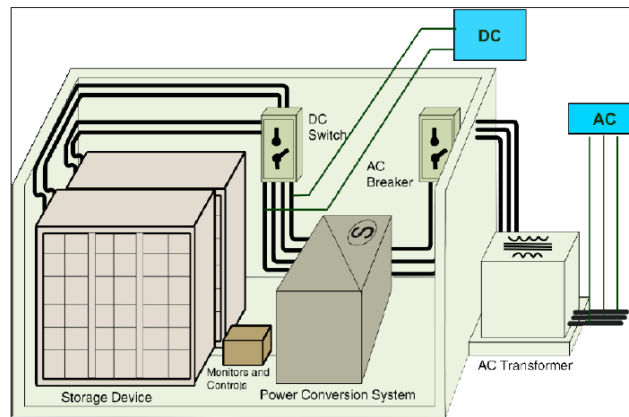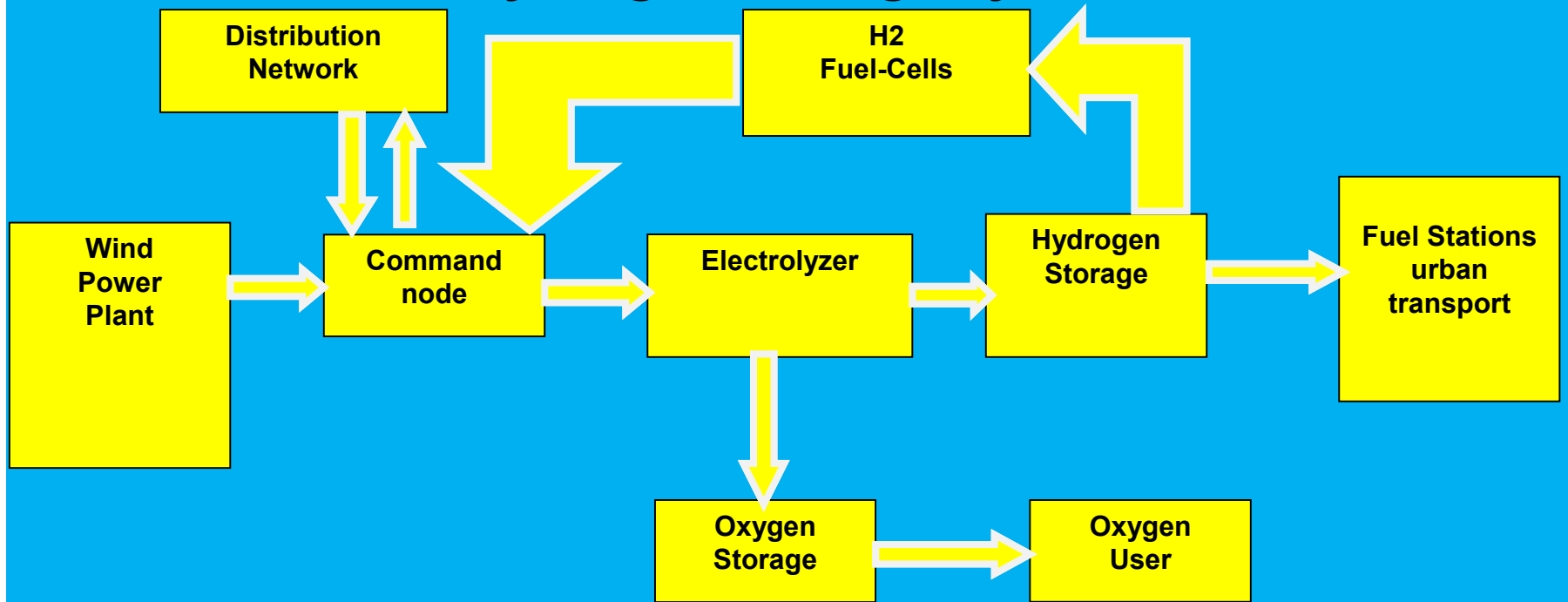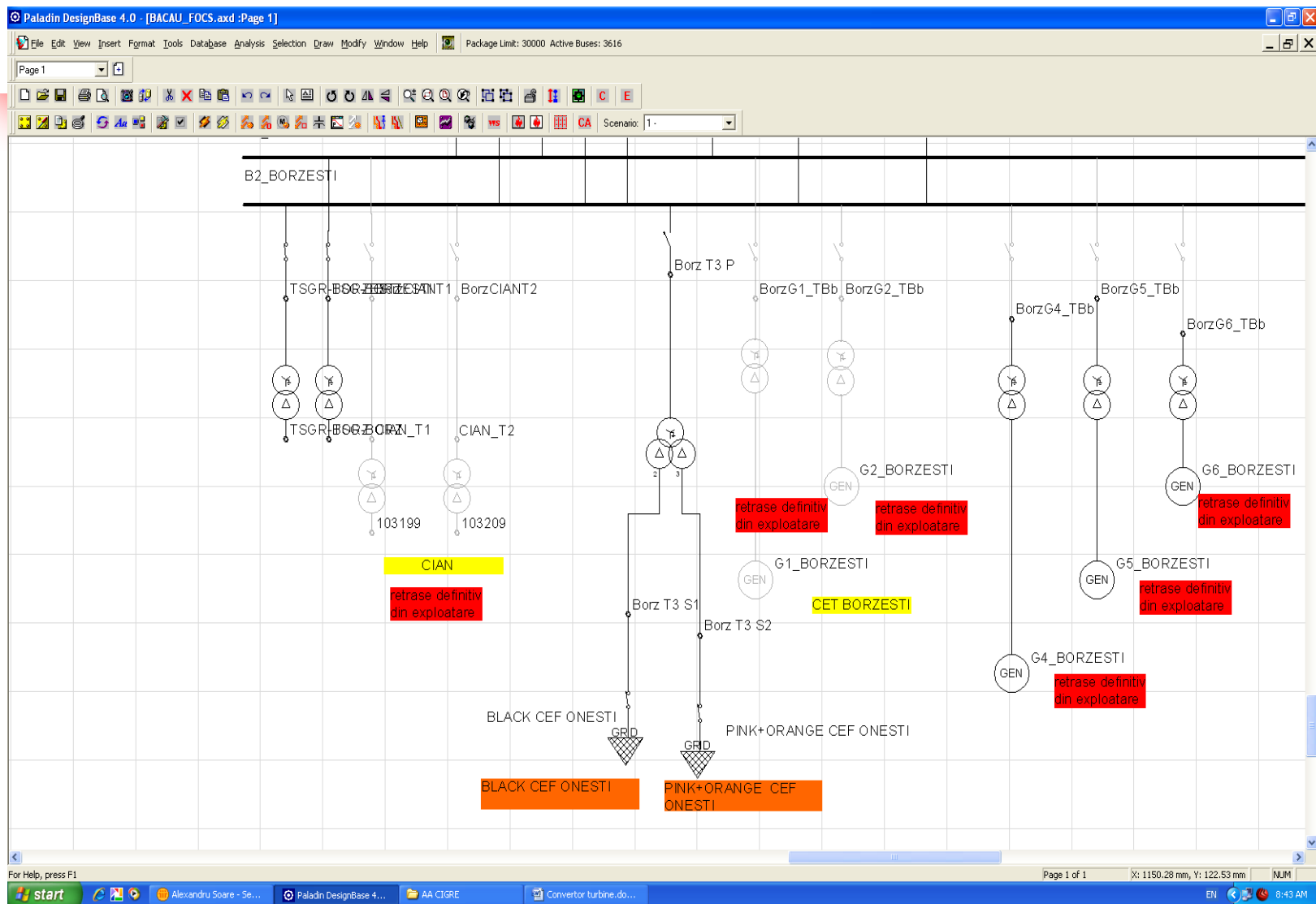
Hydrogen storage system

Fig. Electrical energy from wind power plant with hydrogen storage

ANRE organized a meeting with stakeholders on 6th October 2016, concerning emerging (new technology) used for energy production (according to 631/2016 Regulation). It was proposed like solution for wind and solar energy storage.
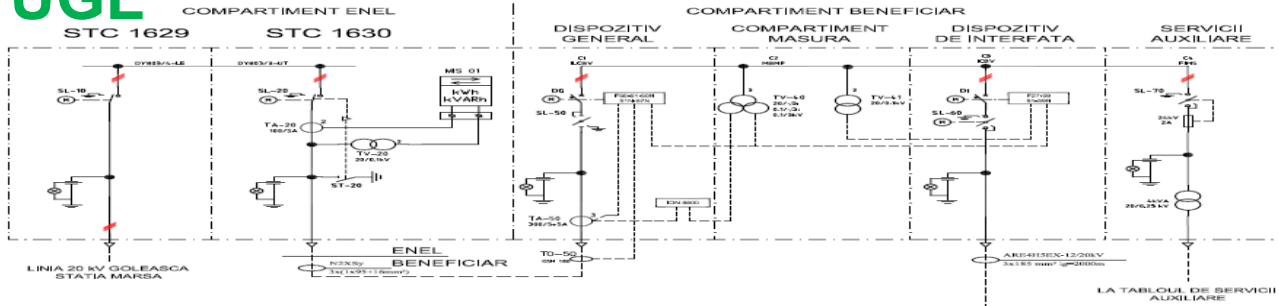
Technical Conformity Certificate Obtaining Process (74/2013 ANRE order)

- **P1 Connecting Contract** (CC) and **Connecting Technical Approval** (CTA) - OTS or OD issue

- **P2 New Capacity Authorization** (ANRE issue)

- **P3 Technical project of power plant** (containing all s/s, overhead lines, underground lines, transformers)

- **P4 Power Plant Controller** : **1) Reactive power Q-U loops** (power factor, voltage control loops) **2) Active power loops** (frequency and active power control)

- **P5 Mathematical Model** (Dynamic model for power plant (**>5MW**) or inverter/turbine (≤**5 MW** and **>1MW**) model, simulations concerning park behavior in transitory and steady-state regimes, conclusions and adopted solutions concerning control schemes)

- **P6 Reactive Study** – Conclusions concerning reactive equipment : static voltage controller (SVC), capacitors bank etc – Requirements: at **Active Power = 0**, Power Plant has to assure **Reactive Power = 0**
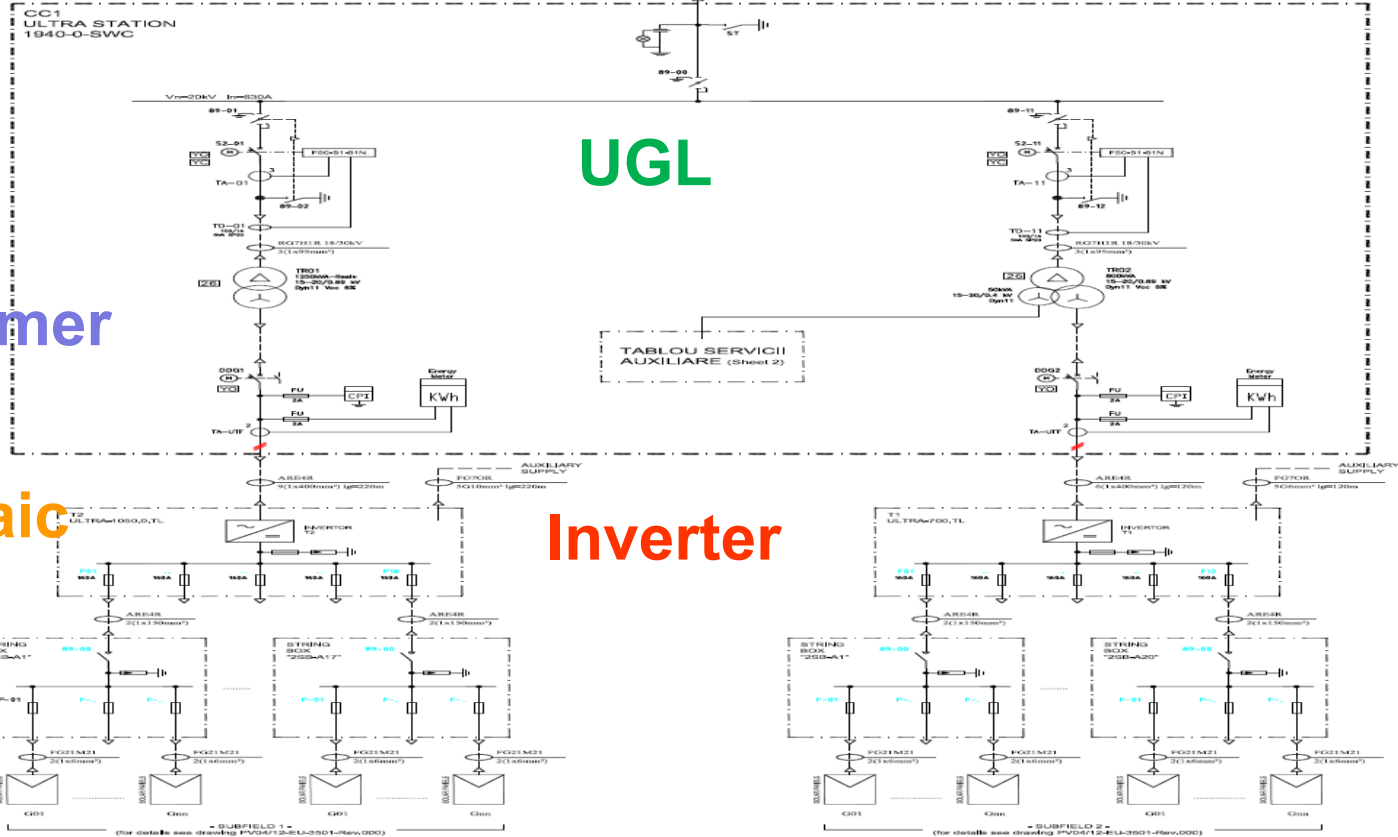
- **P7 Technical Data**

I_{gol}: [%] P_{gol}: [kW]

Inf. reglaj:

Reglaj tens.: U_{pmax}: [kV] U_{pmin}: [kV] U_{plot}: [kV]

U_{scpmax}: [%] U_{scpmin}: [%] U_{scpmed}: [%]

Nivel izolaţiei neutru: Tratare neutru: #

Observaţie: În cazul în care neutrul stelelor transformatorului este legat printr-o impedanţă la pământ, se vor preciza valorile rezistenţei şi reactanţei impedanţei de conectare la pământ.

4. Model date transformator cu două înfăşurări

Fabricaţie: Tip:

Nr. înf.:   Niv. izolaţie neutru: Conex:

S_{nom}: [MVA] $U_{nom\ I}$: [kV] $U_{nom\ J}$: [kV] $U_{scc.\ IJ}$: [%]

$I_{gol\ I}$: [%] $I_{gol\ J}$: [%]

P_{agol}: [kW] $P_{ascc.\ IJ}$: [kW]

U_{pmax}: [kV] U_{pmin}: [kV] U_{plot}: [kV]   Rap. Tens. IJ:

$U_{scc.max}$: [%] $U_{scc.min}$: [%] $U_{scc.\ Nom.}$: [%]

Tratare neutru: #

Observaţie: În cazul în care neutrul stelelor transformatorului este legat printr-o impedanţă la pământ, se vor preciza valorile rezistenţei şi reactanţei impedanţei de conectare la pământ.

5. Model date cablu

Cablu: (Cu sau Al)   Fabricaţie: Tip: Secţiune:

U_n:

Parametrii de secvenţă directă şi homopolară (se precizează T la care sunt măsuraţi.)

$R_+ = [\Omega/m]$ $X_+ = [\Omega/m]$ $C_+ = [\mu Farad/m]$

$R_0 = [\Omega/m]$ $X_0 = [\Omega/m]$ $C_0 = [\mu Farad/m]$

Parametrii de cuplaj mutual (unde este cazul)
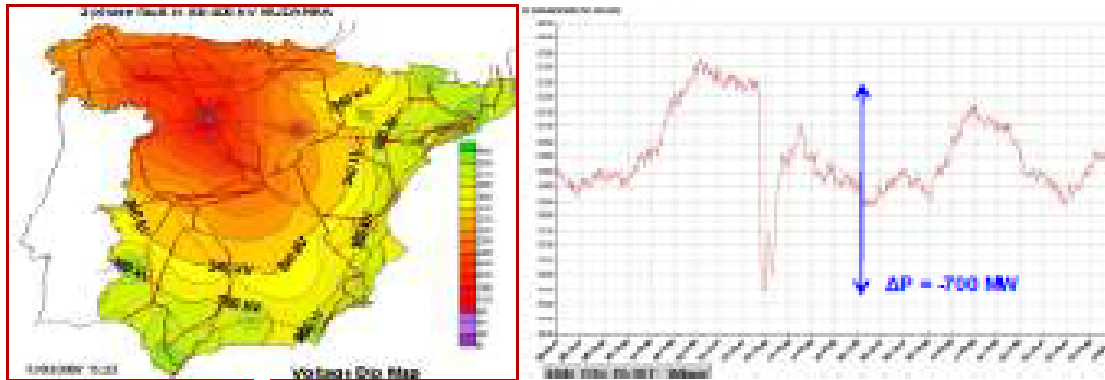
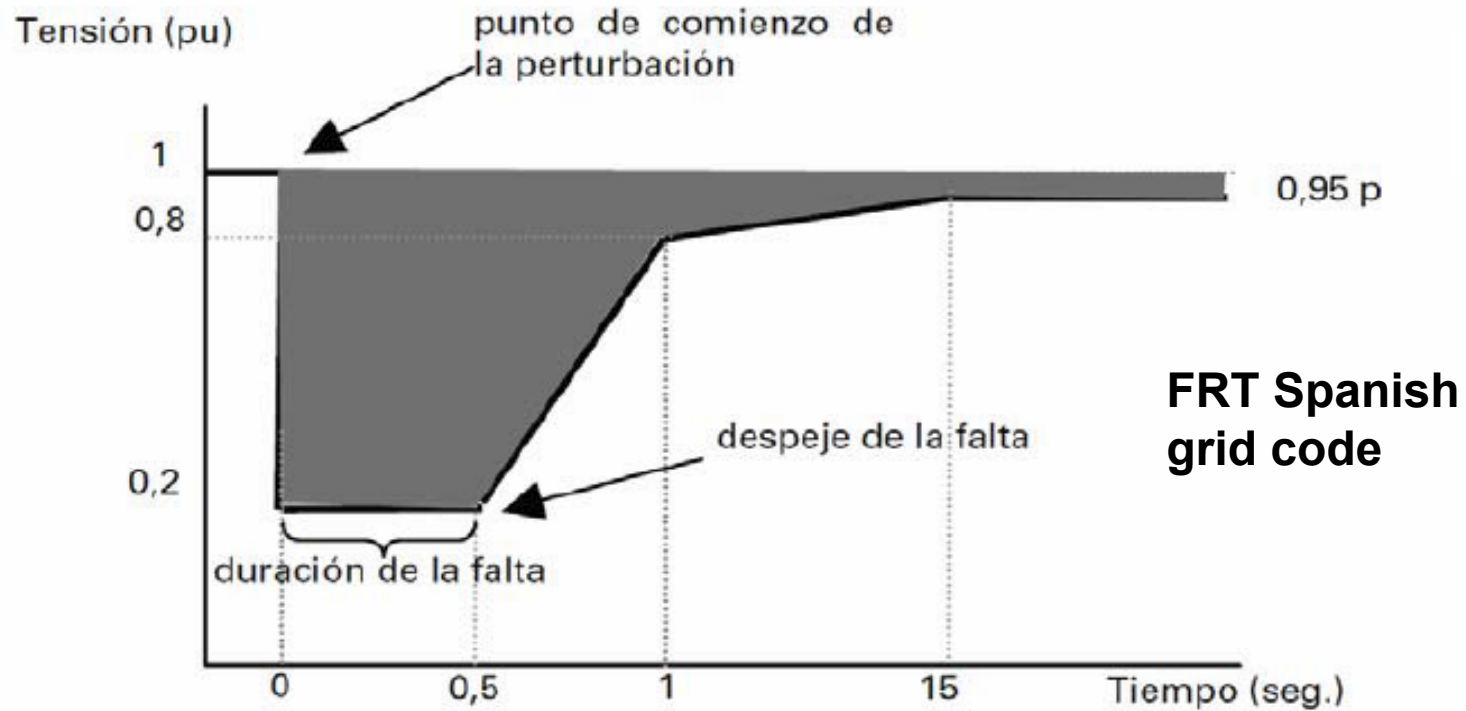lungimea de cuplaj:

$R_{m0} = [\Omega/m]$ $X_{m0} = [\Omega/m]$

EWISS study case (ENTSO-E) wind turbine disconnection

FRT Spanish grid code

Consequences of the incident
- More than 95% of the total capacity (21GW) complies with the above FRT profile in Spain
- About 14 GW of existing wind farms were retrofitted to fulfill the FRT requirements
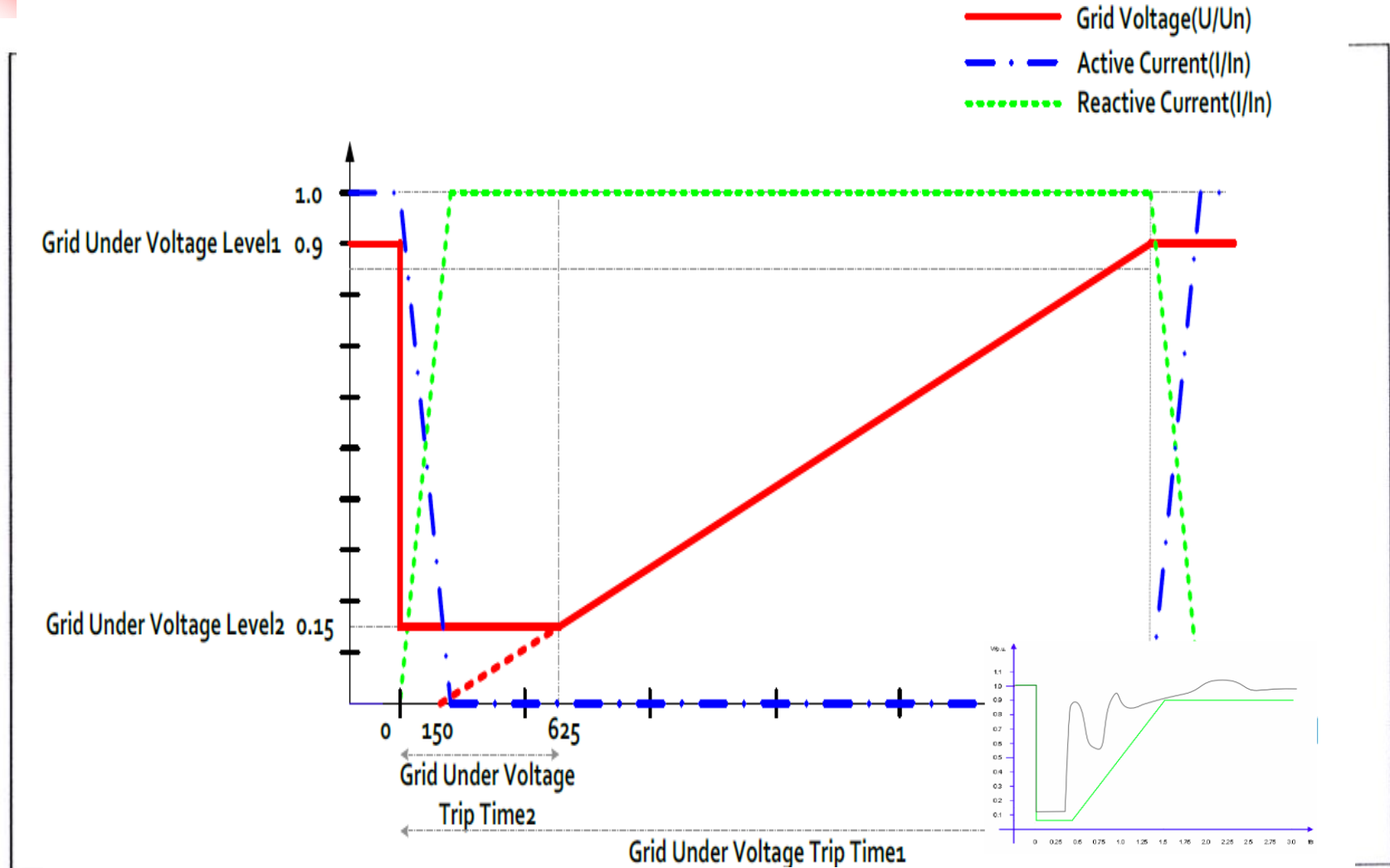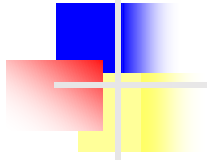
- **P8 Conformity testing and certification** (issued by an authorised company, including *power quality measurement, power performance measurement*)

- **P9** Project/Settings Protections

- **P10** Telecommunications Project necessary for wind/photovoltaic power plant integration in EMS SCADA (OTS) / DMS SCADA (DO)

- **P11** Power Quality

Cost sharing model of producers (including RES) contributing to network connection costs
(11/2014 ANRE Order)

Cost sharing model it is function of voltage level of common connecting point and the power plant capacity

$$T = Tl + TR + TU$$

❑ **T = connecting tariff for a power plant**

➢ **Tl** = cost component for development of electrical network; (necessary to evacuate the authorized power);

➢**TR** = cost for physical connecting installation;

➢**TU** = cost component for **1)** verifying the users installation file and putting into function and **2)** verifying and certificating technical conformity of power plant according to the legal technical requirements in force;

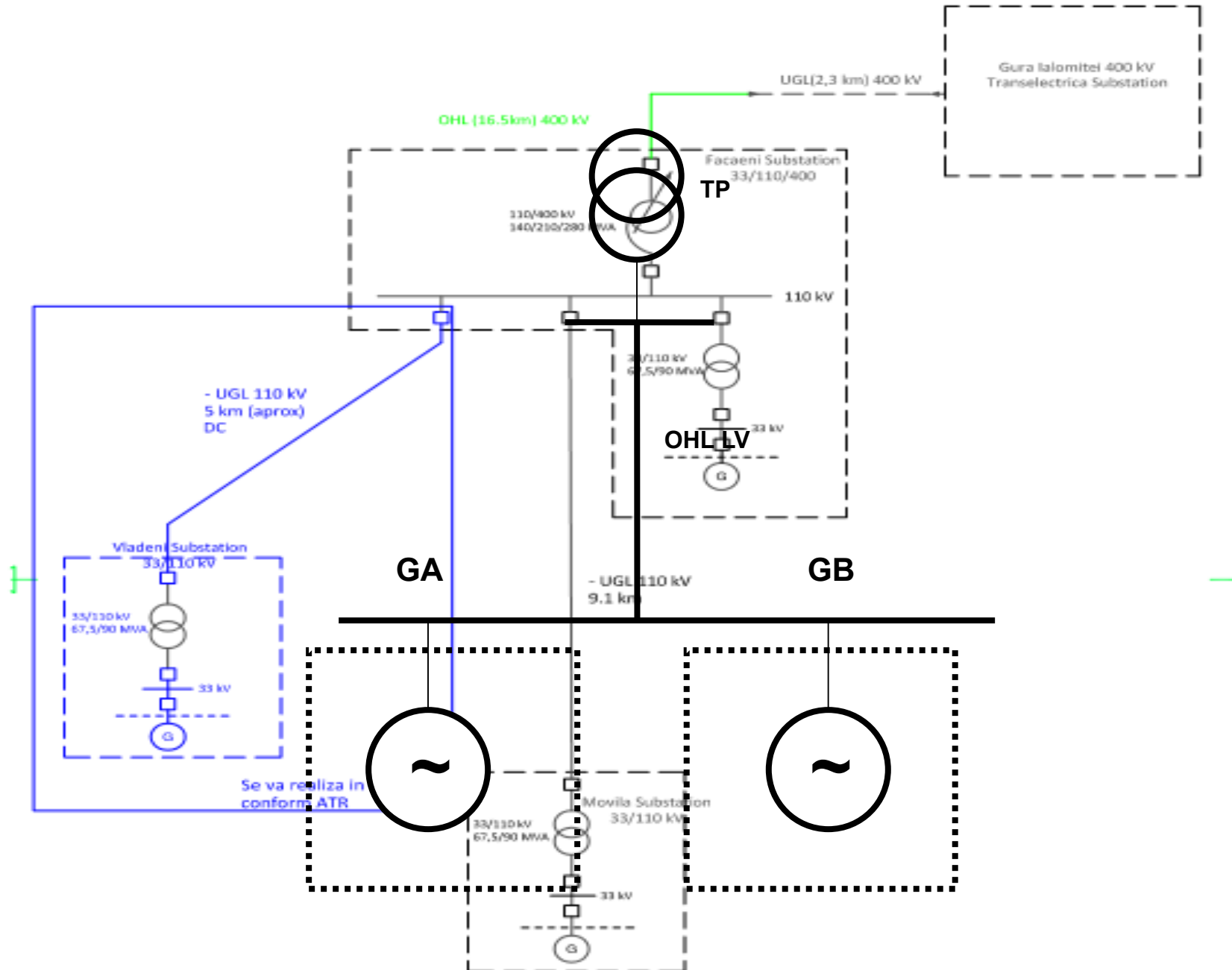$$Tl = Ti \, [lei/MVA] \times S_{authorized \, PP} [MVA]$$

➢Where **Ti** is a specific tariff. It is established function of voltage level of connecting point and $S_{authorized \, PP}$ - the authorized power for supplying into electrical network;

Cost sharing model of producers (including RES) contributing to network connection costs

Establishing specific tariffs for TI component of connecting tariff

1.It will be determined specific tariffs corresponding component elements of an electrical network: **low voltage OHL** or **UGL**, **transformers post** (in concrete envelope or not), medium voltage OHL or UGL, **electrical substations 110 kV/MT**, **110 kV OHL** or **UGL**, **electrical substations 400/220/110 kV**, **220 kV** and **400 kV OHL**.

2.For each type of component element it is established an **reference element** considered representative for that category. For example **110 kV OHL , length 50km, active conductors 185 mm^2 is considered reference element for 110kV OHL** .

3.Specific tariff for an element category it is established like specific cost of reference element.

4.The corresponding cost of the reference element is determined by general device.

Gura Ialomitei 400 kV
Transelectrica Substation

UGL(2,3 km) 400 kV

OHL (16.5km) 400 kV

Facaeni Substation
33/110/400

TP

110/400 kV
140/210/280 MVA

110 kV

33/110 kV
67,5/90 MVA

33 kV

OHL LV

G

- UGL 110 kV
5 km (aprox)
DC

Vladeni Substation
33/110 kV

GA

GB

33/110 kV
67,5/90 MVA

- UGL 110 kV
9.1 km

33 kV

G

Se va realiza in
conform ATR

~

~

33/110 kV
67,5/90 MVA

Movila Substation
33/110 kV

33 kV

G

Cost sharing model of producers (including RES) contributing to network connection costs

Example:

Specific tariff for assessment of the component Tl (cost component for network development), if the connecting point is at the low voltage - into a OHL, is:

$$Ti = i_{LVO} + i_{PTO} \quad [EUR/MVA]$$

i_{LVO} = specific tariff for low voltage OHL , [EUR/MVA]

i_{PTO} = specific tariff for transformer post MV/LV, [EUR/MVA]

$$i_{LVO} = COST_{LVO}/S_{LVO}$$

$COST_{LVO}$ = investment cost for realization of reference element (OHL). In the case of low voltage OHL **reference is chosen an 0.5 km OHL, realized with active conductor, section 70 mm^2**

S_{LVO} = **maximum capacity of the reference element [MVA]**

Cost sharing model of producers (including RES) contributing to network connection costs

Example (cont.):

$$i \, _{PTO} = COST \, _{LVP} / S \, _{LVP} = COST \, _{LVP}/0.25 \quad [EUR/MVA]$$

i_{PTO} = specific tariff for overhead transformer post

COST $_{LVP}$ = specific tariff for overhead transformer post MV/LV [EUR]

S $_{LVO}$ = maximum capacity of the reference element [MVA]. **In the case of overhead transformer post reference is chosen an 250 kVA transformer**
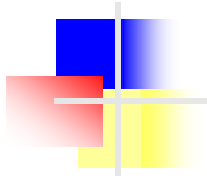
$$Tl = Ti \, x \, S \, _{authorised \, PP} \, [EUR]$$
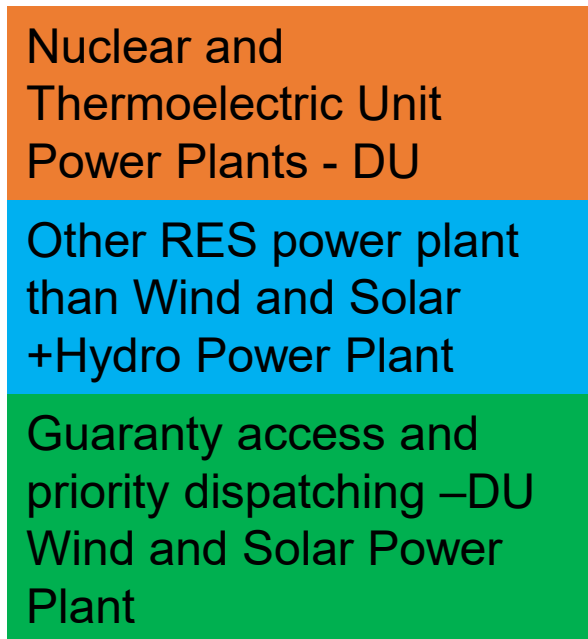
RES Scheduling on Balancing Market (BM)
23/2013 and 60/2013 ANRE Orders

- According to the ANRE Orders Wind/Solar PP with installed power over 5 MW (dispatch units) was integrated into Balancing Market.
- RES producers, according to Balancing Market Rules, pay the cost of their balancing
- 60/2013 ANRE Order : Dispatching Units have guaranty access to electrical network and priority dispatching a) Dispatching Unit – Wind (DU-WPP) b) Photovoltaic DU-PWW c) Dispatching Unit Combined Heat Power (DU-CHP) d) DU Hydro Power Plant e) Dispatching Unit –Nuclear Power Plant(DU-NPP) f) Dispatching Unit- Fossil (DU-F)
- The RES owners are doing daily quantity-price offers (minimum price is 0.1 lei/MWh) and could be selected both at energy increasing and decreasing.
- There are the same rules for RES, except obligation to modify declaration for availability declarations
- At INCREASE, the energy supplied by RES Dispatching Units on BM is selected function of the price, from smaller to higher values
- At DECREASE, the energy supplied by RES Dispatching Units on BM is selected function of the price, from smaller to higher values

RES Scheduling on Balancing Market (BM)
23/2013 and 60/2013 ANRE Orders
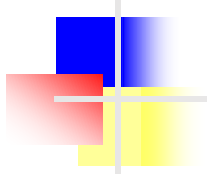### At the same price, the minimum price 0.1 lei/MWh

- INCREASE

- DECREASE

INCREASE column:

Nuclear and Thermoelectric Unit Power Plants - DU

Other RES power plant than Wind and Solar +Hydro Power Plant

Guaranty access and priority dispatching –DU Wind and Solar Power Plant

DECREASE column:

Nuclear and Thermoelectric Unit Power Plants - DU

Other RES power plant than Wind, Solar + Hydro Power Plant

Guaranty access and priority dispatching –DU Wind and Solar Power Plant

TKANK YOU FOR YOUR ATTENTION !