About large wind energy integration in an electrical energy system. Romanian case.

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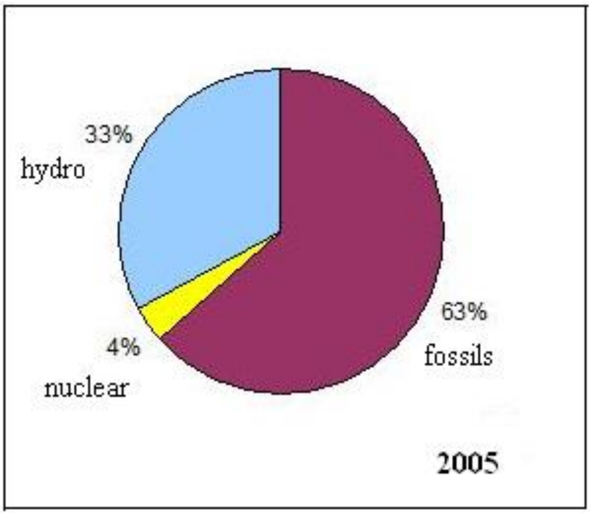
1. Overview of Romanian power system



After the last issue (summer 2008) of the National institute of Statistic publication, "*Anuarul statistic*" the installed power capacities, in Romania, after its origin are 63% from fossils power plant, 33% from hydropower and 4% from nuclear power plant, as it is presented in figure 1. The production of 2005 after its origin is presented in figure 2 and more details are in table 1, where fossils means all capacities where are burned coal, liquid petroleum and natural gas.

Fig. 1 Structure of installed capacities. 2005

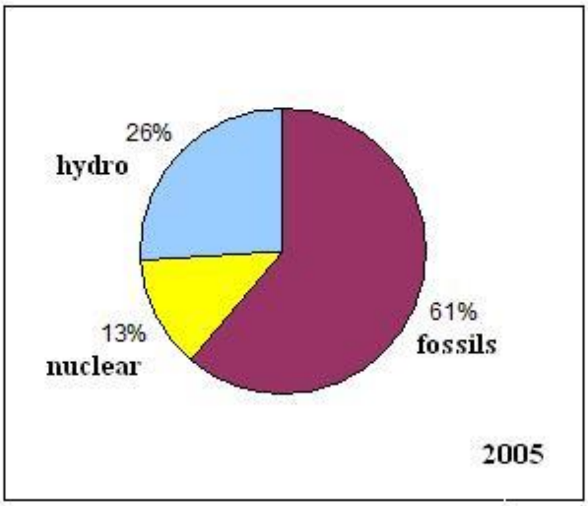
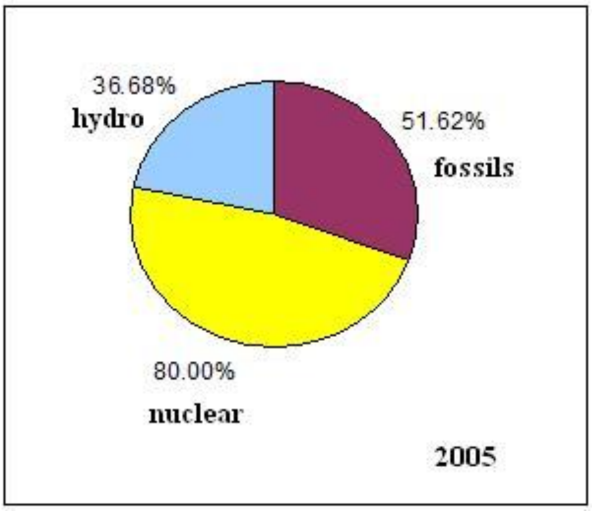


Fig. 2 Structure of energy produced in 2005

Thermo - Coal	41.69%
Thermo - Natural gas	17.42%
Thermo - Petroleum products	1.11%
Nuclear	13.10%
Hydro	25.80%

Table 1.Structure of energy produced in 2005.



From these data results the percentage of usage of the capacities of fossils, nuclear and hydropower, as can be observed down in the figure 3.

Fig. 3 Percentage of every type of power plants capacity used in 2005.

This very low percentage of utilisation of the installed capacities it is due to the closing of many heavy industries after 1989. The only pressures on the energetic system remain the costs, the ecological constraints together with EU obligations towards the percentage of renewable energy.

In the figure 4 can be observed a typically daily load curve in Romania. We can observe that the minimum day average consumption (75%) is reached between 3:00-4:00 in the morning, and the maximum (118%) near the 1:00 pm. (figure 4.) These variations are normal, are predictable, and the management of the system treated them with success.

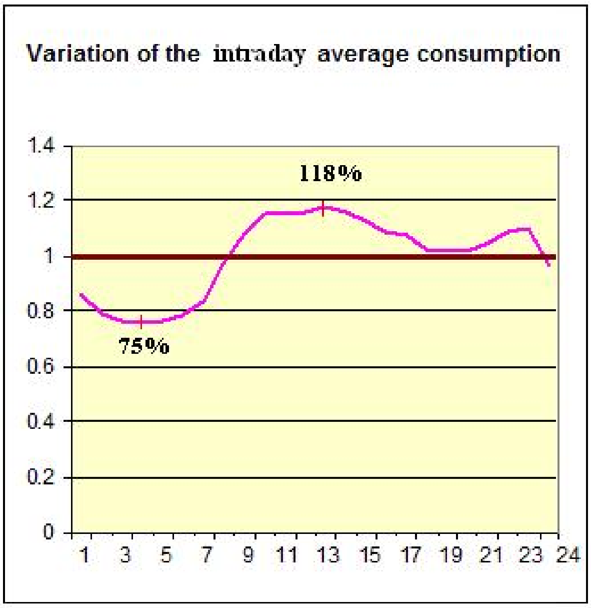


Fig. 4. The intraday consume profile in Romania.

Because the peak daily consume is about 18% over the average, but we consume, today, only 47% of our capacities for the peak predictable consume we managed only 8,5% of our installed capacities in power plants.

For frequency (50Hz) stability, as major parameter, in the national system there are three loops of controls named: primary, secondary and tertiary. The first two are automatic control and the last control is managed by a human operator organized in the national dispatcher. Every power capacity from the about 300 electric power plants is controlled inside of one of these three frequency loops. In the third loop there are rapid power plants like hydro power plant.

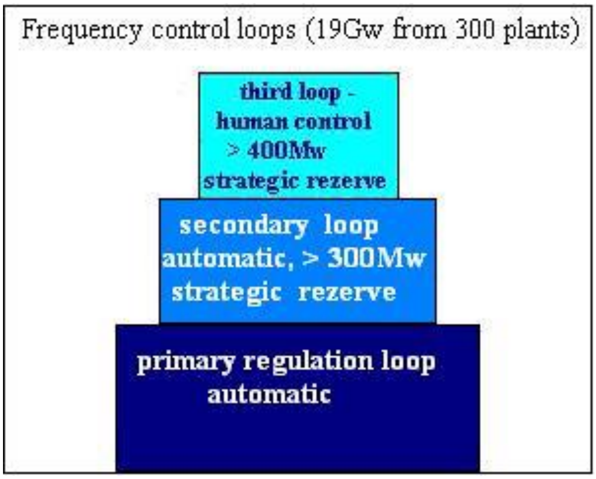


Fig.5 Capacities organized by frequency control loops.

2. The wind energy

The most important thing we must take in account is that this green and renewable energy is arbitrary. To face these arbitrary and unpredictability the overall power management used meteorological prognosis combine with rapid power plant maintained in reserve or with conservation capacities. For the large amount of wind energy to be integrated one must be used besides power reserve capacities, other conservation methods like: pump stations, compressed air storages and boiler systems. All these methods used with wind energy change the arbitrary characteristic of the wind energy in an energy that we can use when it is needed. But this wind with storage facilities ensemble means supplementary investments and has certain efficiency.
The question we expect an answer is how much wind capacities could be attached to a power system without deteriorating its characteristics, in the actual conditions, otherwise without conservation facilities. For our approach we have simplify the problem and considered there is no problem with the energy line and energy transmission.
It is wide recognized that wind power fluctuations in the system are much more difficult to manage than load variations including load forecasting errors.
The Romanian company that manages the grid transmission system, Transelectrica, recently, alleged that it can managed up to 2000MW power from wind turbines, without any development costs. The only positive factor in large wind power integration is the smoothing effect among spatially distributed wind turbines.

3. How much eolian power could be aided to a power system?

3.1The rigidity of an energetic system
It is defined [2] a rigidity function as, R:

$$R = \frac{\sum_i t_i \cdot C_i}{C_t} \quad , \qquad (1)$$

where: C_i is the power capacity after its fuel origin (hydro, nuclear, fossils) that fulfil the today consume, C_t is the total installed power in the national energetic system, T_f are the normalized start time for that type of power plant (see table 2, t_f for hydro=1).

Power plant type	start time (minute)	tf = fuel start time / hydro start time
Thermo coal	1000	125
Thermo petroleum	360	45
Thermo nat. gas	360	45
Nuclear	14000	1750
Hydro	8	1

Tabe 2. The power plants start times

It is computed the value of this function of rigidity, for the Romanian power system, in the 2005. The Romanian total installed power capacity, C_t, is 19.042 MW. As it can be seen below R = 92,43 points.

2005

plant after fuel	tf	capacity in prod. [MW]	Cf/Ct	tf*Cf/Ct

fossils	125	6,222	0.33	40.84
atom	1750	560	0.03	51.47
hydro	1	2,307	0.12	0.12
Rigidity (2005)				**92.43**

We consider the maximum rigidity of our system if all the power plants capacities are used to fulfil the electric energy consume, so we have Rmax=143,78 points, as it can be seen below

2005

plant after fuel	tf	Total capacity [MW]	Cf/Ct	tf*Cf/Ct
fossils	125	12,053	0.63	79.12
atom	1750	700	0.04	64.33
hydro	1	6,289	0.33	0.33
Maximum Rigidity(2005)				**143.78**

In May 2007 Romania has doubled its nuclear capacity, reaching 1400MW, so the rigidity now is higher and the new R, Rmax are a bit higher.

2007

plant after fuel	tf	capacity in prod. [MW]	Cf/Ct	tf*Cf/Ct
fossils	125	6,222	0.33	40.84
atom	1750	1,120	0.06	102.93
hydro	1	2,307	0.12	0.12
Rigidity(2007)				**143.90**

2007

plant after fuel	tf	Total capacity [MW]	Cf/Ct	tf*Cf/Ct
fossils	125	12,053	0.61	76.32
atom	1750	1,400	0.07	124.10
hydro	1	6,289	0.32	0.32
Maximum Rigidity (2007)				**200.74**

Because the absolute value of R or Rmax doesn't tell us very much taken alone we will introduce a coefficient of rigidity,

$$C_{rigid} = \frac{R}{R_{\max}} \quad (2)$$

The rigidity coefficient, Crigid(2005) = 0,643, rises to Crigid(2007) = 0,691, after putting into operation a new 700mw nuclear generator.

3.2. Wind power that can be added to a power system

For the moment avoiding, subtleties like wind forecasts, very good management of all resources we can state that without conservation facilities a large wind power integration is possible only on behalf of rapid power plant like the case of hydro. The unused hydro capacities in the peak consume could be a measure for wind power capacities, Ceolian, that can be added without major problems to the power system and without conservation facilities.

We proposed the following equation:

$$C_{eolian} \leq (1 - C_{rigid}) \cdot K_{kor} \cdot C_{unusedhydro}, \quad (3)$$

Where K_{cor} is a correction coefficient. The average of used hydro power is 2307MW, but in the peak consume the used hydro power could rise to 85% from total installed capacity, otherwise it could rise with 0,85*Ct = 1678Mw. So in the worse case the unused hydro power could lay at the difference between $C_{total\ hydro}$ and $C_{used\ hydro}$ on worse case, that is 6889Mw – (2307 + 1678) Mw.
The unused hydro power, $C_{unused\ hydro}$, is about 2903Mw. The correction coefficient, Kcor, which depends on many other factors, between them a good management of the resources, is very important. This coefficient could be around de 1, e.g. Kcor belong to (0,8 – 1,5).
In the case of year 2005 the relations (3) become $C_{eolian} < K_{cor} * 1036$ MW, and in the case of 2007 the relations (3) become
$C_{eolian} < K_{cor} * 897$ MW
The problem will appears in 2012 when other two nuclear generator should be in use, and till than perhaps 1-2GW wind power are into operation. Following our appreciation method rigidity will appear, as can be seen in the table below:

2012 or after putting into operation of the next to nuclear generators

plant after fuel	tf	capacity in prod.	Cf/Ct	tf*Cf/Ct
thermo	125	6,222	0.30	37.28
atom	1750	2,240	0.11	187.90
hydro	1	2,307	0.11	0.11
Rigidity(2012)				**225.29**

2012

plant after fuel	tf	capacity in prod.	Cf/Ct	tf*Cf/Ct
thermo	125	12,053	0.58	72.22
atom	1750	2,800	0.13	234.88
hydro	1	6,289	0.30	0.30
Maximum Rigidity (2012)				**307.40**

So, the Crigid (2012) will rise up to 0,733, and the wind energy that could be added to Romanian power system figure out at least to 775Mw. At least, because we do this calculus it can be maintained the today figure for energy consume, for the peak consume and neglected other future changes in our power system. Obviously other more accurate calculus could be done, but our intention was to set up method to appreciate how many wind power capacities could be added without additional conservation facilities. This method can be refined taking in account capacities maintain in reserve and so on.
Considering Kcor = 1, the results are summarized in table below:

year	2005	2007	2012
Crigid	0,643	0,691	0,733
Nuclear (Mw)	700	1400	2800
Wind add w/t conservation facilities (Mw)	1036	897	775
Wind power in used, 2008	1Mw		
Wind power application	~1500Mw		

4. Conclusions

In conclusion, Romania must be prepared until adding into operation of the next 2 nuclear generators, intended in 2012 to have at least 1Gw power in conservation facilities. Since ‘70th a hydropower with 1Gw pump was designed, but never realised. Compressed air and direct consume water heating are new reliable means to integrate large wind power in the energetic system, besides pump storage. Another complementary issue could be a new concept of a smart “energetic system”.

5. References

[1] ***, Anuarul statistic 2008, National Institute of statistics, Bucharest, Romania.
[2] O. Capatina, Hydro-eolian hybrid structure, Research contract. Phase II. I.P.A. Cluj Napoca, 2008.
[3] Ioan Vădan, Dan Căpăţână, et all., Hydro-Eolian Hybrid Power Plant, Proccedings of PSC’07, International power systems Conference, Timisoara, 2007, Romania.
[4] O.Căpăţină s.a. – Hydro-Eolian Energetical Ensamble, Proceedings of AQTR, 2007, Cluj-Napoca, Romania.