SOME ASPECTS OF THE WIND ENERGY INTEGRATION INTO THE NATIONAL POWER SYSTEM

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INTRODUCTION

In the policy documents that are already approved [1,2] or are still in design phase [3] are set out ambitious objectives of the Republic of Moldova in the field of development of renewable energy, including the production of electricity from renewable energy sources -RES-E. Thus, by the year 2020, the share of renewable energy in the total consumption of energy resources will be 20 % and the share of RES-E in the annual electricity production will reach 10 %. Three RES-E technologies of production that can be used in Moldova – wind, photovoltaic energy and hydraulics, one of the most promising is the first. Studies confirm the existence of the technical potential of wind ranging between 650 and 1000 MW [4]. In order to achieve a 10 % share of RES-E in the total consumption of electricity will have to integrate into the national power grid of 200-250 MW wind power.

At the same time, wind power brings more variability and uncertainty to power systems. This has potential impacts on power system reliability and efficiency. These impacts can in principle be either positive or negative; however, large amounts of wind power usually turn even positive impacts to negative at some stage of penetration level with regards to the cost of integration. A number of significant integration studies from Europe and the USA has concluded that accommodating wind electricity penetrations of up to 20 % is technically feasible [5-7].

For Moldova, besides technical issues related to the integration of wind power, there is another one - related to the power tariff increase for final consumers. Harnessing renewable energy sources involves developing a support of RES-E generation from renewable sources. This will lead to increased tariffs. In this paper the focus is on analyzing the impact of the introduction of the Feed-in-Tariff (FiT) support scheme on integration into the national power of 200 MW wind power. The authors attempt to answer to the question: How much will the electricity tariff increase and how will the evolutions be in the near future?

1. WIND ENERGY PENETRATION LEVEL DEFINITIONS

Wind energy penetration level is characterized by the following definition [6]:

1. Wind energy penetration factor (WEPF) is generally defined as the ratio of the total amount of wind energy (*WE*) produced in a year to the total annual electricity demand energy (*TED*) produced in a year for a given region

$$WEPF = \frac{WE}{TED}. \quad (1)$$

2. Wind power penetration factor (*WPPF*) looks at how the total installed wind power capacity (*WP*) in a certain region is related to the peak load (*PL*) in this region

$$WPPF = \frac{WP}{PL}. \quad (2)$$

According to [7] in 2009 Moldova's Power System has recorded consumptions shown in table 1. Under these conditions WEPF will not exceed 0,13 and WPPF-0,25.

Table 1. Moldova's Power System gross electricity demand & peak load, 2009

Indicator	Moldova's Power System	Right-bank
Gross electricity consumption, GWh	5792	3980
Peak load, MW	1146	810
Eventual installed wind power, MW	-	200
Eventual wind power production, GWh	-	526
WEPF	0,09	0,13
WPPF	1,17	0,25

At the first phase of wind potential exploitation (200 MW installed wind power) the wind energy penetration factor is less than 0,2 and will not appear major technical problems. It remains to estimate what will be the impact on tariffs for the final consumers. The following presents the methodology and results of the calculations.

2. FIXED FEED-IN TARIFF SUPPORT MECHANISM

FiT support scheme is currently being implemented in 63 countries around the world, including 20 of the 27 EU Member States, as the main instrument to support RES-E generation. The main principle of the FiT policy is to provide guaranteed prices for fixed periods of time for RES-E (usually 10-20 years). These prices are generally offered in a non-discriminatory manner for each kWh of electricity produced. The state does not fund renewable electricity market. All costs are passed on to the consumer, taking into account that according to the law 160 [8] suppliers are forced to buy all the RES-E energy production. These suppliers will transfer the cost to the final electricity consumers.

In the past two years in the Republic of Moldova there is a revival of foreign and local investors interests in the production of RES-E, but first comes wind power (EEE). Government intentions to implement FiT scheme for RES-E support served as the impetus. In order to determine FiT values for different RES-E technologies, assessment of affordability of feed-in tariffs for individual groups of electricity, the Ministry of Economy has initialized these studies in 2011. The Consulting Company ECA (Economic Consulting Associates) from the United Kingdom was contracted by the EBRD for the execution of studies: "Development of Renewable Energy Support Mechanisms for the Republic of Moldova". According to this study the calculated FiT for wind energy is equal to10,11 c€/kWh.

3. CALCULATION METHOD

3.1. Assumptions

Increasing tariffs for end consumers in the event integration of PE= 200 MW wind power was calculated accepting the following assumptions:

1. The wind power integration in National Power Greed (NPG) takes place in 2012.
2. In 2012 the global income for three distribution companies - Natural Gas Union Fenosa, RED Nord and RED Nord West, is accepted equal to global income in 2011 in the absence of wind energy.
3. Procurements, market share held by the three distribution companies and useful electricity supplied to consumers correspond to the year 2011.
4. Power production (EE) by local combined heat and power plant - CHP (CET-1 and CET-2, CET-North) and hydro power plant - HPP Costesti Stinca, electricity purchased from the CTEM (Moldovan thermal power plant on the left bank) corresponds to the year 2011.
5. Regulated tariffs for electricity and the price of energy purchased from CTEM correspond to the year 2012.
6. Capacity factor, K_C, of eventual wind farms is allowed to be equal to 0,3.
7. The distribution companies are obliged to purchase all the produced wind energy. The amount of energy is proportional to the market share held.
8. The average exchange rates have been accepted for the period of 8 months of the year 2012: 1 $ = 12,02 MDL; € 1 = 15,3914 MDL; € 1 = $ 1,28.

3.2 Input Data

The numerical values of the indicators, the information source or the calculation formula are presented in table 2.

Tabel 2. Input Data

Nr.	Indicators, formulae	Symbols, values	Source
1.	EE purchasing by the distribution companies, P_i, mln. kWh	P_{UF}=2902,5; P_N=662,9; P_{NV}=344,1.	[9]
2.	EE total purchasing, mln. kWh. $P_{tot}= P_{UF} +P_N +P_{NV}$	P_{tot}= 3909,5	[9]
3.	Market share held by distribution companies, $P_{Di}=P/P_{tot}$.	P_{DUF}=0,742; P_{DN}=0,170; P_{DNV}=0,088.	-
4.	EE produsedon the right side of the river Nistru, CHP, HPP Coste ti, mln. kWh.	Total: EL=849; EL_{CET1}=59,8; EL_{CET2}=655,9; EL_{CETN}=57,8; EL_{CHE}=75,5.	[9]
5.	EE regulated tariffs produced by CHP and HPP Coste ti, ani/kWh	T_{CET1}=166,14; T_{CET2}=158,63; T_{CETN}=137,11; T_{CHE}=17,0.	[10]

6.	The regulated weighted tariff, Bani/kWh $TP=\frac{1}{EL}(EL_{CET1}T_{CET1}+ + EL_{CET2}T_{CET2}+EL_{CETN}T_{CETN}+ + EL_{CHE}T_{CHE})$	TP=145,1 or 9,43 c€/kWh	-
7.	EE purchasing from the local producers according to the market share held, mln. kWh. $EL_i= P_{Di}\cdot EL$	EL_{UF}=630,0; EL_N=144,0; EL_{NV}=74,7.	-
8.	EE cost purchased from the local producers, mln. MDL. $CL_i= EL_i\cdot TP$	CL_{UF}=914,1; CL_N=208,9; CL_{UF}=108,4.	-
9.	EE purchased from the CTEM, mln. kWh. $CE_i=P_i-EL_i$	CE_{UF}=2272,5; CE_N=518,9; CE_{NV}=269,4.	-
10.	EE cost purchased from CTEM, the cost of 6,9 c$/kWh or 82,9 Bani/kWh, mln. MDL. $C_i^{CTEM}=CE_i\cdot P_{CTEM}$	C_{UF}^{CTEM}=1883,9; C_N^{CTEM}=430,2; C_{NV}^{CTEM}=223,3.	-
11.	Total cost for EE purchasing from the local producers and CTEM, mln. MDL. $C_i=CL_i+C_i^{CTEM}$.	C_{UF}=2798,0; C_{UF}=639,1; C_{UF}=331,7;	-
12.	EE useful delivery to the consumers, mln. kWh, V_i.	V_{UF}=2449,3; V_N=580,1; V_{NV}=292,8.	[9]
13.	EE tariffs for the final consumers MDL/kWh,T_i	T_{UF}=1,58; T_N=1,71; T_{NV}=1,73.	[11]
13.	Cashing from sales at regulated tariffs, mln. MDL, $I_i=V_i\cdot T_i$.	I_{UF}=3869,9; I_N=992,0; I_{UF}=506,5.	-
14.	Global income obtained from sales. mln. MDL, $VG_i=I_i-C_i$.	VG_{UF}=1071,9; VG_N=352,9; VG_{NV}=174,8.	-
15.	*EEE* production, mln. kWh. $EEE= 8760\cdot K_C\cdot P_E\cdot 10^3$	EEE=526.	-
16.	*EEE* purchasing by distribution companies, mln. kWh. $EEE_i=P_{Di}\cdot EEE$	EEE_{UF}=390,3; EEE_N=89,2; EEE_{NV}=46,3.	-

3.3. The tariff calculation formulae of electricity supplied to final consumers

If wind power integrated into the NPG is equal to zero, the overall income of the distributioncompany (see p. 14 of the table 2) will be calculated using the formula

$$VG_i=I_i - C_i = V_i\cdot T_i - EL_i\cdot TP - CE_i\cdot P_{CTEM}, \quad (3)$$

where tariff Ti for the final EE consumers is

$$T_i=\frac{VG_i+EL_i\cdot TP+CE_i\cdot P_{CTEM}}{V_i} \quad (4)$$

In the case of wind power integration PE into NPG, the same global income will result from the expression

$$VG_i=I_i - C_i=V_i\cdot T^E{}_i - EL_i\cdot TP - EEE_i\cdot FiT-(CE_i-EEE_i)\cdot P_{CTEM} \quad (5)$$

where tariff TEi for the final consumers in the case of wind power integration PE into NPG is

$$T^E{}_i=\frac{VG_i+EL_i\cdot TP+EEE_i\cdot FiT+(CE_i-EEE_i)P_{CTEM}}{V_i} \quad (6)$$

The tariff increase will constitute the difference between (6) and (4)

$$(T_i^E-T_i)=\frac{EEE_i(FiT-P_{CTEM})}{V_i}. \quad (7)$$

From (7) results that the power tariff increase for final consumers is proportional to the difference between the FiT and price of power delivered from CTEM.

4. RESULTS

4.1. The EE tariff increase for different FiT's values

It has been analyzed three scenarios:

- It is approved the FiT proposed by ECA equal to 10,1 c€/kWh or 1,554 MDL/kWh;
- It is approved the FiT equal to weighted tariff to EE produced and regulated on the right side of Nistru River: FiT = 9,43 c€/kWh or 1,451 MDL/kWh;
- It is approved the FiT equal to 8,5 c€/kWh or 1,308 MDL/kWh.

The results are presented in table 3 and in the graphic form in Figure 1.

Table 3. The EE tariff increase for the final consumers, %

The distribution Company	FiT value, c€/kWh		
	10,10	9,43	8,50
GN Union Fenosa	7,3	6,3	4,8
RED North	6,5	5,6	4,3
RED North West	6,6	5,7	4,4

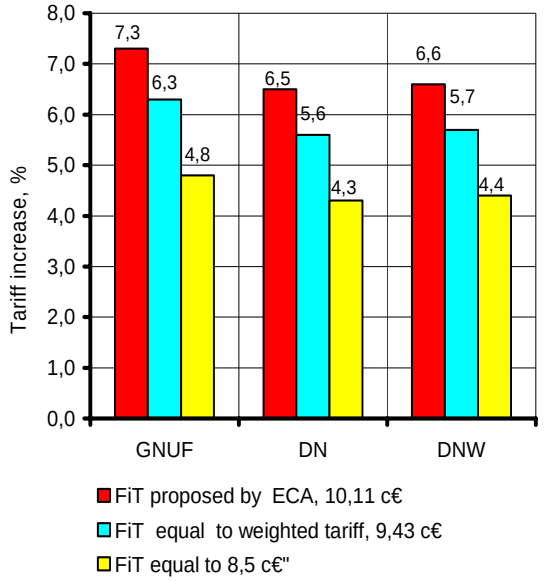

Figure 1. Tariff increasing for end users: wind power is equal to 200 MW

4.2. The FiT vis-à-vis EE cost trend delivered from CTEM

In the period 2008-2012 the cost of electricity supplied from the CTEM grew from 4,15 to 6,9 c$/kWh or 1,66 times,. Using exponential approximation that yields a 13,6 % annual increase.

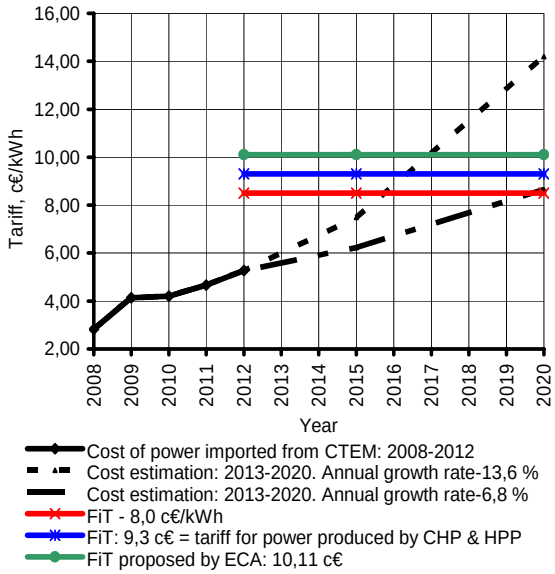

Figure 2. Cost estimation trend for power delivered from CTEM vis-à-vis the FiT

Assuming the maintenance of this trend, by 2020 the cost will reach the figure of 14,2 c€/kWh. In the case of double reduced of the annual cost, growth will reach the figure of 8,65 c€/kWh. Graphical interpretation of EE cost delivered by CTEM vis-à-vis the FiT value is shown in Figure 2. The cost of electricity supplied from the CTEM will be equal to 10 c€/kWh or with the FiT value, by the year 2017. If the FiT value equal to 8,5 c€/kWh is accepted, and the annual increase will be two times smaller the current trend, then equality will occur in 2019-2020.

4.3. The FiT tariff vis-à-vis the weighted tariff trend for EE produced by CHP and HPP

Not less important is the comparative analysis of FiT with the regulated weighted tariff for power produced on the right side of the river Nistru, in other words, at the CHP and HPP Coste ti. In 2011 the weighted tariff was equal to 145,1 bani/kWh or 9,43 c€/kWh. The weighted tariff growth rate constituted 19 % in the period 2004-2012. It has been assessed two scenarios of increasing the weighted tariff in 2013-2020: with the annual rate of 5 and 10 %. The results are presented in Figure 3.

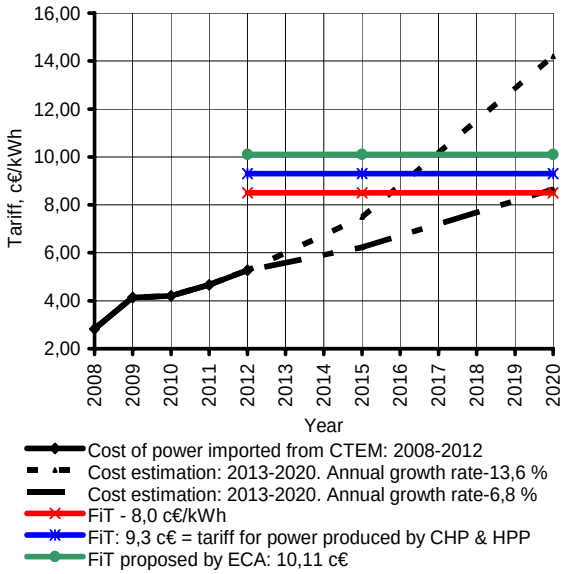

Figure 3. Cost estimation trend of regulated weighted tariff for power delivered from CHP and HPP vis-à-vis the FiT

5. ADDITIONAL COSTS FOR BALANCING POWER

The wind speed and power variability, uncertainty in the demand for electricity is causing

higher costs, as a result of the value increase of the power reserves on short-term, purchased by the system operator. Studies in this field have not been made in the Republic of Moldova, and the only solution is to apply the results obtained in the EU countries and the USA [12-14]. In spite of the differences in the results and methods, these studies found that, in general, if the penetration factor of wind energy does not exceed 20 % the balancing costs are limited to c$ 0,14 – 0,56/kWh wind power. In the first approximation, it is admitted the maximum costs equal to 0,56 c$/kWh wind power. The additional annual costs: $0{,}56 \cdot 10^{-2} \cdot 526 \cdot 10^{6} = 295 \cdot 10^{4}$ $/year. The electricity delivered usefully (2011) $0{,}56 \cdot 10^{-2} \cdot 526 \cdot 10^{6} = 295 \cdot 10^{4}$ $/year.

Balancing cost: $C_B = \frac{295 \cdot 10^4}{3322{,}2 \cdot 10^6} = 0{,}00089$ $/kWh or 1,0 bani/kWh.

CONCLUSIONS

An eventual integration into NPG 200 MW wind power will not create major technical problems because wind energy penetration factor shall not exceed 0,13.

There will be an insignificant power tariff rise delivered to the final consumers. The maximum tariff increase for final consumers connected to the distribution networks will constitute 7,3 % (11,5 bani/kWh) for the company GN Union Fenosa, 6,5 % (11,1 bani/kWh) for North RED and 6,6% (11,4 bani/kWh) for Nord West RED.

If in 2013-2020 will be kept the current growth trend, then in 2015-2017 the EE price purchased from CTEM will exceed those of FiT values.

The FiT maximum value (proposed by ECA) is larger than the current weighted electricity tariff for power produced by CHP and HPP with 17,7 %. Over one year after the entry into service of eventual wind farms the weighted tariff will exceed the FiT value.

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Bibliography

1. *Strategia Națională de Dezvoltare Moldova 2020. http://particip.gov.md*

2. *Programul național pentru eficiență energetică 2011-2020. Monitorul Oficial Nr. 197-202, 18.11.2011*

3. *Strategia Energetică a Republicii Moldova până în anul 2030. www.mec.md*

4. Sobor I. *Potențialul energetic eolian al Republicii Moldova: modele, estimări, măsurări şi validări. Meridian Ingineresc, nr.2, 2007, p. 59-66. ISSN 1683-853X*

5. *IEA Reaport Wind Task 25: Design and operation of power systems with large amounts of wind power: State-of-the-art report. VTT Technical Research Centre of Finland. VTT Working Papers. October 2007.- 147 p. ISBN 978-951-38-6633-4*

6. *Wind Energy: the facts. An Anallyses of Wind Energy in the EU - 25. EWEA, 2004.- 330 p. www.ewea.org*

7. *European Wind Integration Study (EWIS) Towards a Successful Integration of Wind Power into European Electricity Grids. January 2007 – 36 p.*

8. *Legea energiei regenerabile Nr. 160 din 12.07.2007. 17.08.2007 în Monitorul Oficial Nr. 127-130.*

9. *Raport de activitate al Agenției Naționale pentru Reglementare în Energetică a Republicii Moldova în anul 2011. www.anre.md*

10.*Hotărârea ANRE nr. 429 din 21 octombrie 2011 privind tarifele la producerea energiei electrice, energiei termice şi de livrare a energiei termice consumatorilor finali. www.anre.md*

11. *Hotărârea ANRE nr. 470 din 11.05.2012 privind tarifele la energia electrică. MO nr.92/577 din 15.05.2012. www.anre.md*

12.Wiser R. Z. et all. *Wind Energy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. /-2011. 109 p.*

13. Gross R., P. Heptonstall D. Anderson T. Green M. Leach, and J. Skea. *The Costs and Impacts of Intermittency:An assessment of the evidence on the costs and impacts of intermittent generation on the British electricity network. Imperial College London, London, UK, 2006. 112 p.*

14. Holttinen H. P. et all. *Design and Operation of Power Systems with Large Amounts of Wind Power: Phase One 2006-2008. VTT Technical Research Centre of Finland, Espoo, Finland. – 2009, 200 p.*

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