SCENARIOUS OF MOLDAVIAN POWER SYSTEM DEVELOPMENT TO MERGE ENTSO-E

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REZUMAT. În lucrare se face analiza scenariilor de dezvoltare a sistemului energetic al Republicii Moldova pentru varianta de funcţionare în paralel cu ENTSO-E (European Network of Transmission System Operators For Electricity) şi se cercetează rentabilitatea şi eficienţa tehnică a soluţiilor propuse în cazul dezicerii de la funcţionarea sincronă cu sistemul energetic al Ucrainei.

Cuvinte cheie: linie de transport a energiei electrice, pierderi de putere, schimb de putere, putere activă şi reactivă, regim normal.

ABSTRACT. The paper analyzes the options for the development of transport networks in Moldova in the implementation of parallel work scenarios with ENTSO-E (European Network of Transmission System Operators For Electricity) and research the feasibility and technical effectiveness of the proposed options in case of missing of synchronous work with Ukraine power system.

Keywords: electrical transmission line, power system interconnection, power exchange, active and reactive power, power losses, normal mode.

1. INTRODUCTION

One of the directions of scientific researches in Institute of Power Engineering of Academy of Sciences of Moldova is connected with elaboration of Republic Moldova power Strategy development. The geographical position of the Republic assumes the feasibility of different scenarios to solve this problem. Realization of various computational models implies corresponding modes of power system analysis of the parameters which allows us to estimate the technical efficiency of the proposed solutions.

At modeling of promising mode of high-voltage network the baseline was database of the maximal modes which format is made in PSS/E obtained by analysis of projections for the years 2015-2020 under the project of power transmission systems development in the Black Sea Region (Black Sea Transmission Project). The database prepared by the project, contains complete information on the energy systems of Black Sea countries: Russia, Romania, Georgia, Ukraine, Bulgaria, Armenia, Moldova, Turkey, as well as the network equivalent of adjacent countries: Estonia, Latvia, Lithuania, Belarus, Poland, Slovakia, Hungary, Macedonia, Serbia, and Azerbaijan.

The entire volume of data has been converted and adapted for use as an input information for standard software package „RASTR" calculating the normal modes, which is used in Institute of Power Engineering of ASM as a research tool in solving such problems.

2. GENERAL CHARACTERISTIC OF RESEARCH OBJECT

Based on the 2015-2020 winter peak mode was elaborated computational model of connection of Moldovan power system to ENTSO-E without Ukraine.

The realization of this scenarios involves the following activities:

- Turn-off the high-voltage line 330kV Balti – Dniester HPP;
- Turn-off of two circuit HV line 330kV Cotovsc-Rabnita;
- Allocation of 330 kV buses section at Moldavian State Distinct Power Plant (MSDPP) to connect on them of HV line 330kV MSDPPS-Kotovsk, MSDPP-Usatove, MSDPP-Novoodeska, MSDPP-Artsyz;
- Beginning of 400kV HV line construction Balti-Suceava;
- Construction of 330kV HV lines Balti-Rabnita and Straseni-Rabnita in order to supply Rabnita power node from the west;

- Inclusion on the synchronous operation with Romanian energy system of 400kV HV line MSDPP-Isaccea;
- Turn off of the intersystem 110kV HV lines with Ukraine (Vasilevka-Red Okny, MSDPP-Starokazache, MSDPP-Razdelinaia, MSDPP-Belyaevka, Vulcanesti-Bolgrad-1, Vulcanesti Bolgrad-2, Vulcanesti-Etalon, Vulcanesti District -Renee, Etulia-Budjac, Dniester HPP-BSZ , Ocnita-Mines, Nemia-Otaci, Soroca-Poroghi, Nelipovtsy-Larga).

The parameters newly introduced in computation model of HVL are presented in Table 1.

Table 1

The parameters of inserted HVL

Name of line	Wire	l(km)	R(Ohm)	X(Ohm)	b(μSm)
Rabnita 330-Balti 330	AC-300	104	4.45	22.71	-337.0
Rabnita 330-Straseni 330	AC-300	91	4.05	20.54	-306.0
Balti 400-Suceava 400	AC-300	128	4.1	39.42	-412.2

Attempts to build this computation model without input of 400kV HV line Balti-Suceava were unsuccessful because of the unacceptable level of voltage reduction at the sites of the northern part of Republican power and, consequently, cannot get the normal steady state.

The main characteristics of the regime adopted for the analysis were as follows: the flow distribution in the transport network, the level of active power losses in the elements of a network, active and reactive power generation and load in the nodes, the voltage level at the nodes, etc.

The main parameters that characterize the flow distribution, as well as the topology of the current version, imposed on the flow chart (for the base case is shown in Figure 1).

The resulting basic mode can be characterized as follows:

1. The realization of this scenario does not increase the reliability of electricity supply power in Moldova, as instead of the power supply from Dniester HPP through single circuit 330kV HV line Balti-Dniester HPS, we obtain the connection of 400kV single circuit HV line (Balti-Suceava), which must be built. Thus, any increase of the transport supply does not occur.

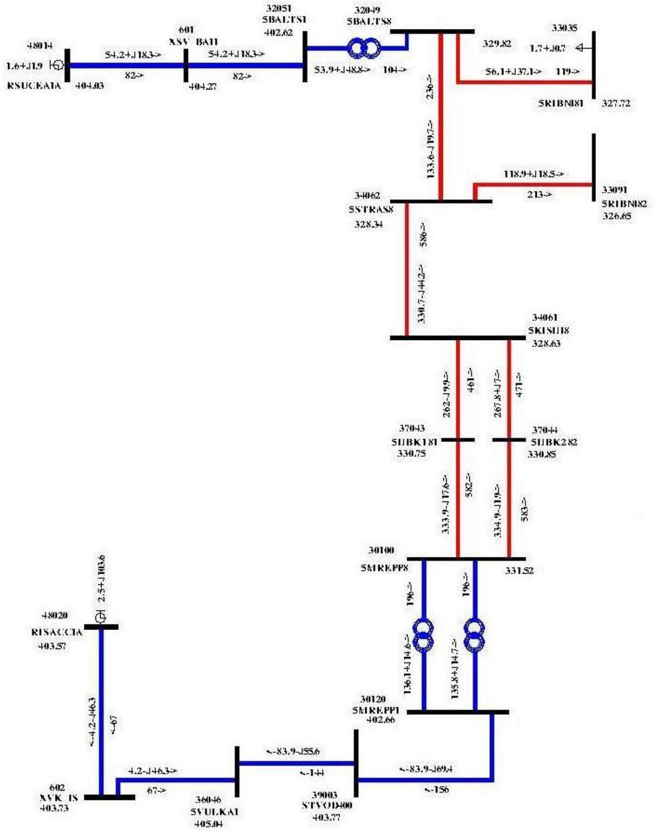

Fig. 1. Parameters and topology of base mode.

2. Instead of relatively independent power supply of Ribnita energy node through 330kV two-circuit HV line from side Kotovsk substation of Ukrainian energy system it is necessary to organize the electricity supply of 330kV Rabnita substation both from Balti and Straseni, lines which are also necessary to build.
3. Also, reducing the reliability of power supply of the republic are 400kV HV line MSDPP-Vulcanesti-Isaccea and 330kV single-circuit HV line Chisinau-Straseni.
4. Thus the entire Moldovan energy system is essentially "hangs" on two one-circuit 400kV HV lines in the North and South that does not improve the energy security indicators of Moldova.

Main characteristics of the regime in the base case on adjacent energy systems are given in Table 2.

Table 2

Main characteristics of the mode on base case

N_D	District	P_{gen}, MW	Q_{gen}, MVAR	P_{load}, MW	Q_{load}, MVAR	ΔP, MW	ΔQ, MVAR	P_{ext}, MW	Q_{ext}, MVAR
3	Moldova	1126,8	197,7	1151,4	434,4	33,9	-311,9	-58,6	75,2
4	Romania	10266,8	2256,9	9416,5	3449,2	281,1	-873,1	569,2	-319,2
7	Ukraine	32461,6	13520,1	30468,6	10032,6	1049,4	5078,9	943,6	-1591,4
1	The rest of the network	78262,1	30640,1	77768,9	32591,1	1947,5	-3786,5	-1454,2	1835,5
	UES	**122117,3**	**46614,7**	**118805,4**	**46507,3**	**3311,9**	**107,4**	**0,0**	**0,0**

The notations in table 1 are following: N_D – number of district marked on the map; P_{gen} – active power generated; Q_{gen} – reactive power generated; P_{load} – active power used; Q_{load} – reactive power used; ΔP – total active losses; ΔQ – total reactive losses; P_{ext} – external active power exchange with all adjacent power systems; P_{ext} – external reactive power exchange with all adjacent power systems.

From the analysis of the provided information it can be seen, that the active power losses in the power system of Moldova are 33.9MW, and in the power system of Romania - 281.1MW, i.e. practically unchanged (280.8MW) compared to the basic regime (prior to joining the ENTSO-E), which provides synchronous operation of Moldova power system with Ukraine [1]. It should be noted that disconnecting of power system Moldova from Ukraine and it connect to the ENTSO-E leads to a substantial increase of active power losses (from 916.4MW up to 1049.4MW, i.e. with 133 MW or 12.7%) in the power system of Ukraine. These losses are mainly related to lower voltage levels at the sites of Odessa when disconnecting power connections of (110-330) kV.

The values of the mutual exchange of active power in Moldova, Ukraine and Romania in the basic mode are presented in Table 3. Analyzing the data presented in this table, we can evaluate the energy exchange between the two countries during the scenarios calculations in the future. So, it is clear that since the Moldovan power system operates in parallel with ENTSO-E, energy exchange with Ukraine is zero, and with the Romanian energy system becomes equal to 58.7 MW, which corresponds to the total exchange through 400kV HV lines Balti-Suceava and Vulcanesti-Isaccea. It should be noted that using of 400kV HV line Vulcanesti-Isaccea (exchange flow of 4.2 + j46.3) is weak in the base mode.

Information that allows analyzing the active losses in all elements of the Moldovan energy system for each class of voltage to the base case is presented in Table 4.

Table 3

The main characteristics of the mode in baseline

№	Name	Ps, MW
1	The rest of the network	
4	Romania	510,5
7	Ukraine	943,6
3	Moldova	0,1
3	Moldova	
7	Ukraine	0,0
1	The rest of the network	-0,1
4	Romania	58,7
4	Romania	
1	The rest of the network	-510,5
3	Moldova	-58,7
7	Ukraine	
1	The rest of the network	-943,6
3	Moldova	0,0

Table 4

Components of active power losses

U_{nom}	ΔP, MW	$ΔP_{load}$, MW	$ΔP_{OL}$, MW	$ΔP_{tr}$, MW	$ΔP_{id}$, MW
Moldova	33,9	30,2	26,75	3,45	3,71
6kV		0,07		0,07	
10kV		0,6		0,6	
15kV		1,35		1,35	
35кkV		0,38		0,38	
110kV		16,29	16,25	0,04	0,41
330кkV		11,05	10,22	0,84	2,3
400kV		0,46	0,29	0,18	1

The notes in table 3 and table 4 means: Ps – power exchange between each power systems separately; ΔP – summary active power losses; $ΔP_{load}$ – active power losses in the load; ΔP_{OL} – active power losses in the Overhead Lines; ΔP_{tr} – active power losses in the transformers because of the load; ΔP_{id} – idle active power losses in transformers.

From table 4 it is seen that main load active power losses are concentrated in 110kV and 330kV lines.

The above model is taken as the base for the analysis of the possible development variants of Republican power system in the frame of the approved strategy development.

3. ANALYSIS OF OPTIONS FOR INCREASING THE RELIABILITY OF POWER SUPPLY WITHIN THIS SCENARIO

As noted above, one of the factors significantly reduce the reliability of the Republican power system network is the presence of single-circuit 330kV HV line Chisinau-Straseni. Therefore, it was designed and analyzed version of strength of this connection by the second circuit in the frame of developing scenarios of Republican power system. Parameters of the second circuit, proposed to the construction on this section, taken the same as an existing.

The results of the steady state modeling under these conditions are presented in graphical form of mode parameters on Figure 2 and show that an increase in the cross section of Chisinau-Straseni leads to a more substantial loading Transit 330 kV in a northerly direction from 330.7MW up to 365.6MW, some unloading of Balti-Suceava HV line and loading of HV line Vulcanesti-Isaccea.

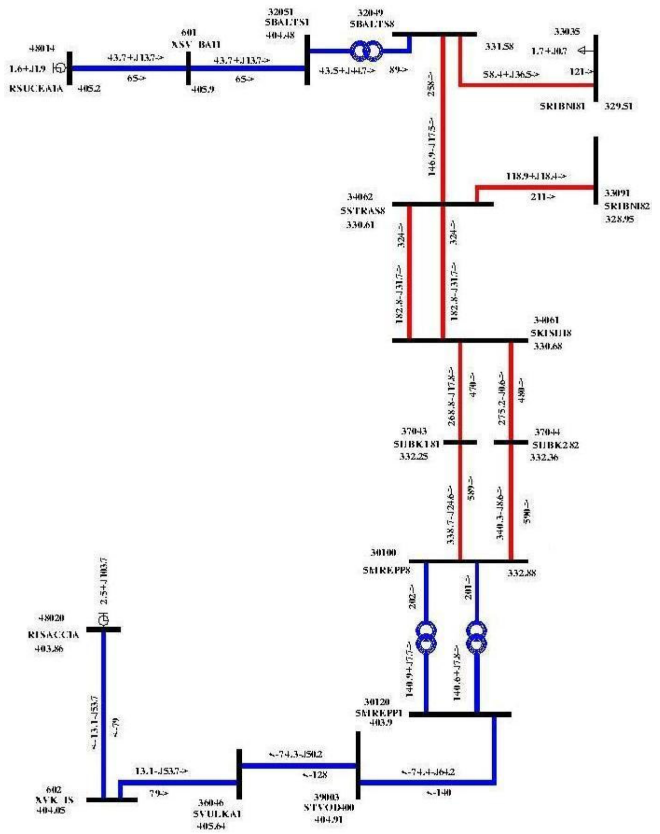

Fig. 2. The mode parameters at strengthening of section Chishinau-Straseni

At synchronous work with NTSO-E and disconnecting from the Ukrainian energy system is unused 330kV HV line Balti-Dniester HPP. Thus, as in the currently existing situation, the entire north and north-west of the republic receives electricity through 110 kV networks. For a more efficient use of 330kV HV line Balti- Dniester HPP authors have proposed to build on tap from this power line to the substation Donduseni with its reconstruction, and transfer to the 330 kV, in addition to the variant with increased section Chisinau-Straseni. This step will allow the use a part of the 330kV HV line Balti- Dniester HPP by passing electricity to the northern and north-western districts of the republic directly through 330 kV network and, presumably, unloading the network of 110 kV, which is currently being implemented supply.

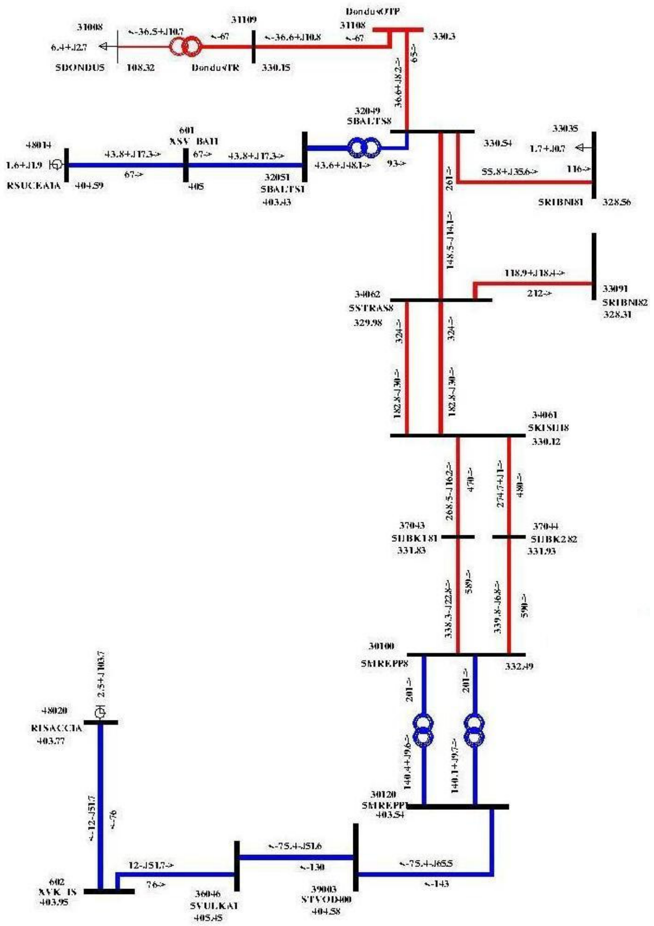

Fig. 3. The mode parameters at transfer of Donduseni substation to 330kV

The results of the computation experiment, which implements the above, are presented in the form of the parameters, put on a network diagram Figure 3.

From the analysis of flow distribution in the system forming network can be seen that 330kV HV line Balti-Donduseni tap is loaded (flow = 36.6 + j8.2) in a northerly direction, which was to be achieved.

Should be noted that this power is distributed mainly from the 110 kV network in the 330 kV network, as flows through 400kV HV lines Suceava-Balti and Vulcanesti-Isaccea changed very little in comparison with the option of Figure 2.

Table 5

The main mode indexes for analyzed scenarios

N_D	District	ΔP(MW)			P_{gen} (MW)			P_{ext}(MW)		
		baseline	1	2	baseline	1	2	baseline	1	2
3	Moldova	33,9	32,4	31,1	1126,8	1126,8	1126,8	-58,6	-57,1	-55,8
4	Romania	281,1	280,8	280,9	10266,8	10266,8	10266,8	569,2	569,5	569,5
7	Ukraine	1049,4	1049,4	1049,4	32417,8	32461,6	32461,6	943,6	943,6	943,6
1	The rest of the network	1947,5	1947,4	1947,4	78198,2	78260,3	78259,1	-1454,2	-1456,0	-1457,2
	UES	**3311,9**	**3310,1**	**3308,8**	**122009,6**	**122115,4**	**122114,2**	**0,0**	**0,0**	**0,1**

As show the analysis of the information provided in Table 5, the inclusion of the second circuit of overhead line Chisinau-Straseni (column 1) leads to some reduction in active power losses in the power system of the country from 33.9MW up to 32.4MW, i.e. on 1.5MW or 4.4%.

At realization of the variant with the transfer to the Donduseni substation on voltage 330 kV can be seen that the losses of active power drops to 31.1MW, representing a decrease of 1.3MW (4%) (column 2) compared to option 1 and 2.8MW (8.2%) compared to the baseline. The active power losses in the power system of Romania and neighboring power systems remain practically unchanged.

As show the data in Table 6, with the inclusion of the second circuit 330kV Chisinau-Straseni losses are reduced as in the 330 kV network and a network of 110 kV.

Table 6

The main losses characteristics in the analyzed variants

	Baseline (MW)			
U_{nom}, kV	ΔP_{load}	ΔP_{OL}	ΔP_{tr}	ΔP_{id}
Moldova	33,9	30,2	26,75	3,45
400	0,46	0,29	0,18	1
330	11,05	10,22	0,84	2,3
110	16,29	16,25	0,04	0,41
	Variant 1			
U_{nom}, kV	ΔP_{load}	ΔP_{OL}	ΔP_{tr}	ΔP_{id}

Moldova	32,43	28,69	25,31	3,38
400	0,4	0,22	0,18	1,01
330	10,54	9,75	0,79	2,32
110	15,34	15,34	0,04	0,41
	Variant 2			
U_{nom}, kV	**ΔP_{load}**	**ΔP_{OL}**	**ΔP_{tr}**	**ΔP_{id}**
Moldova	31,1	27,33	24,07	3,26
400	0,39	0,22	0,17	1,01
330	10,45	9,74	0,71	2,35
110	14,15	14,11	0,04	0,42

For the second version the loss reduction occurs mainly in the 110 kV network (from 15.34MW up to 14.11MW), indicating a noticeable discharge of 110kV networks (8%) in the northern part of the country. The considered scenario allows, along with an increase in the reliability of electricity supply in Moldova, to achieve a significant reduction in the level of active power losses, which is important.

4. CONCLUSIONS

- ✓ As a result of adaptation of the database on modes of transport networks of the Black Sea basin for the period 2015-2020 years was created and tested a working model for the calculation and analysis of normal modes in the case of merge of Moldova power system to ENTSO-E, which was adopted as a baseline for future studies.
- ✓ The full characteristic on the research object was done.
- ✓ Based on the basic regime a number of computational models was built, which allowing calculate the various options for the development of a Republican power system network in the frame of possible merge to the ENTSO-E.
- ✓ A comparative analyzes of technical efficiency for calculated variants was done.
- ✓ The most optimally and most technically efficient development scenario, which can significantly reduce the active power losses and improve reliability of power supply of the republic, was selected.
- ✓ The research results can be used in formulating the basic principles of the strategic development of the main high-voltage power network in Moldova.

BIBLIOGRAPHY

[1] **L.Calinin, D.Zaitev, M.Tirsu, I.Golub.** *The develompent variants of Moldova transport network in case of parallel operation with Ukraine power system,* Regional energetical problems. nr.1(18)/2012. www.ie.asm.md.

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