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Analysis of power system of the Republic of Moldova in the context of the interconnection to ENTSO-E and accesion to European Union

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Abstract. *The need to analyze the Moldovan power system comes in the context in which the Republic of Moldova has become a serious candidate for accession to the European Union, and one of the conditions of accession is the interconnection to electricity european networks – ENTSO-E, which is the network of the 39 transmission system operators from 35 countries in the European Union. Against the background of military instability following the war between Russia and Ukraine and dependence on the Russian power system, interconnection with other States within the European Union becomes a strategic objective of ensuring energy security and implicitly national and European. Since Romania is the only credible potential strategic energy partner, all possibilities for cross-border interconnection must be considered. In order to have a safe and secure cross-border interconnection with Romania and implicitly with the European Union, the Moldovan power system must meet some criteria recommended by ENTSO-E: consumption coverage; primary power regulation; secondary frequency-power regulation; voltage regulation; operation safety at criterion (N-1) elements; anti-damage measures. Because an power system can be vulnerable to various threats, risks or internal or external dangers, the authors aim to critically analyze the Moldovan power system, as it generates critical infrastructures that ensure the energy and national security of the Republic of Moldova.*

Keywords*: Power system, ENTSO-E, Energy security.*

1. General information on ENTSO-E

ENTSO-E (European Networks of Transmission System Operators for Electricity) is the European network of 39 electricity transmission system operators from 35 countries in the European Union and extends beyond borders, as shown in Figure 1.

ENTSO-E was established and received legal mandates under the EU's third Internal Energy market Package in 2009, which aims to further liberalize gas and electricity markets in the EU. On 27 June 2008, 36 European electricity transmission system operators signed in Prague a declaration of intent to create ENTSO-E, which was established in Brussels on 19 December 2008 and became operational on 1 July 2009, and the former UCTE associations, ATSOI, UKTSOA, NORDEL and BALTSO have become part of ENTSO-E, while providing data by their predecessors in the public interest.

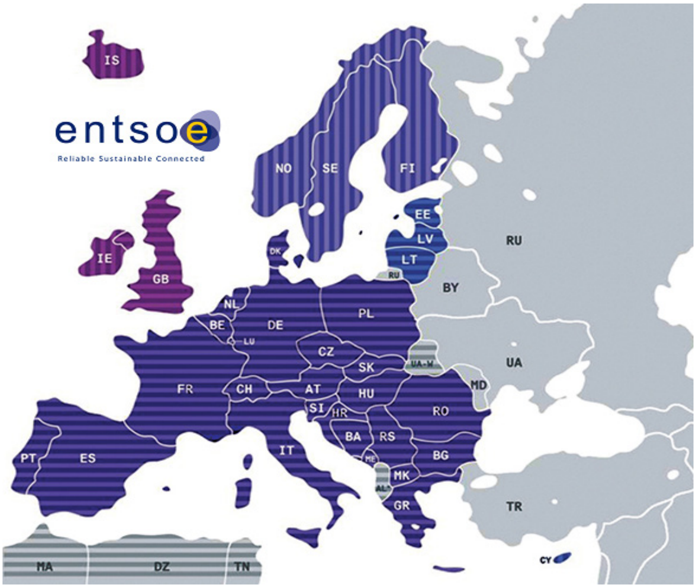

Figure 1. Map of ENTSO-E

ENTSO-E Member States: *Austria, Albania, Bosnia and Herzegovina, Belgium, Bulgaria, Switzerland, Cyprus, Czech Republic, Germany, Denmark, Estonia, Spain, Finland, France, Greece, Croatia, Hungary, Ireland, Iceland, Italy, Lithuania, Luxembourg, Latvia, Montenegro, Northern Ireland, North Macedonia, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Sweden, Slovenia, Slovakia, Ukraine (observer Member).*

The interconnection of an power system is the main way to increase its reliability and security without affecting energy independence and provides emergency aid without the need to install and maintain a hot reserve of important power and the criteria for participation in interconnected operation (The ENTSO-E recommendations concern 6 major aspects of the operation of an energy system:

consumption coverage; primary power regulation; secondary frequency-power; voltage regulation; safety of operation under criterion (N-1) elements; anti-damage measures) [1].

In order to ensure the energy security of the Republic of Moldova and in the context of accession to the European Union, the synchronous connection to the ENTSO-E European electricity system is necessary and mandatory.

In this regard, in 2006, the joint request of the Republic of Moldova and Ukraine for a synchronous connection to the ENTSO-E system was submitted through a single block. Over several years, specialists of the Moldelectrica of the Republic of Moldova, Ukrenergo of Ukraine and Transelectrica of Romania, carried out the necessary documents preparation works.

At the moment, the technical and economic analysis on the possibility of carrying out the given project is carried out, the necessary steps are analyzed and processed, which must be taken by the Power System of the Republic of Moldova and the Power System of Ukraine for the possibility to enter ENTSO-E.

2. Power System – a system that generated critical infrastructures

In order to ensure the well-being and security of citizens, the Moldovan state has to provide a number of facilities for them, such as: Access to drinking water, sewerage, natural gas, electricity, medical care, to lead a normal and decent life, that society be happy.

These extremely important facilities are provided by certain infrastructures, which fall into three broad categories [9] :

- *ordinary infrastructure* – is a framework structure that ensures the construction and operation of a system;
- *special infrastructures* – with a consistent role in the functioning of systems and processes and a high degree of stability and security in the overall mechanisms of economic and social life of regional interest;
- *critical infrastructures* – are usually determinants of instability, security and security of systems and processes, playing an important role in the economic, social, political and military processes.

The vulnerability of these infrastructures creates a number of risks and threats to them, thus endangering societal life, creating malfunctions and causing extreme harm to society. Critical infrastructures thus become indispensable to society, without which the State and its mechanisms cannot function and ensure societal well-being, and their protection and/or security becomes a major national and European objective, determining the representatives of the Member States of the European Union to take action to identify and manage any risk or threat that could endanger the well-being of European citizens.

In this context, the Ministry of Infrastructure and Regional Development, through the Moldelectrica, must designate all the national and European critical infrastructures within the National Power System and have *Security Plans at the Operator* for each critical infrastructure, and these plans must be drawn up by the *Security Liaison Officers* [3].

In the Republic of Moldova the activity of electricity transmission, management and dispatching of the National Power System is carried out through the enterprise Moldelectrica, which is also the system operator.

The Power System of the Republic of Moldova works in sync with the Power System of Ukraine [2].

<u>Energy infrastructure</u> (power plants):

- *Gas-based thermoelectric plants – installed power: 2383,4 MW;*
- *Coal-fired thermal power plants – installed power: 1600 MW;*
- *Fuel oil-based thermoelectric plants – installed power: 2778 MW;*
- *Hydroelectric power plants – installed power: 64 MW;*
- *Renewable energy plants – installed power: 4 MW;*
- *main power plants:*
    - CET 1 Chișinău – installed power: 66 MW;
    - CET 2 Chișinău – installed power: 240 MW;
    - CET Bălți – installed power: 24 MW;
    - CHE Costești – installed power: 16 MW;
    - CHE Dubăsari – installed power: 46 MW;
    - CERS Moldova (Cuciurgan) – installed power: 2520 MW;
    - Other generating sources – installed power: 87 MW.

<u>Power infrastructure</u> (power substations and overhead lines), as shown in Figure 2*:*

- *2 (two) 400 kV power substations (strategically important):*
    - Vulcănești;
    - CERS Moldova.
- *5 (five) 330 kV power substations (strategically important):*
    - CERS Moldova;
    - Răbnița;
    - Chișinău;
    - Strășeni;
    - Bălți.
- *9 (nine) 110 kV power substations for interconnection with Ukraine (commercial exchanges):*
    - Etulija;
    - Vulcănești;

- CERS Moldova;
- Valilevik;
- Soroca;
- Otaci;
- Ocnița;
- Brich;
- Larga.

- *4 (four) 110 kV power substations for interconnection with Romania (commercial exchanges):*
    - Cioara;
    - Ungheni;
    - Gotești;
    - Costești.
- *1 (one) 400 kV overhead line for cross-border interconnection with Romania (stability and reliability of the power system):*
    - Vulcănești – Isaccea;
- *1 (one) 400 kV national overhead line (stability and reliability of the power system):*
    - Vulcănești – CERS Moldova.
- *7 (seven) 330 kV overhead line for cross-border interconnection with Ukraine (stability and reliability of the power system):*
    - CERS Moldova – Novoodeska;
    - CERS Moldova – Usatove;
    - CERS Moldova – Podilska;
    - CERS Moldova – Artsyz;
    - Răbnița – Podilska (circuit 1);
    - Răbnița – Podilska (circuit 2);
    - Bălți – Dnistrovska HPP.
- *3 (three) 330 kV national overhead line (stability and reliability of the power system):*
    - CERS Moldova – Chișinău (double circuit);
    - Chișinău – Strășeni;
    - Strășeni – Bălți.
- *15 (fifteen) 110 kV overhead line for cross-border interconnection with Ukraine (commercial exchanges):*
    - Etulija – Budzhak;
    - Vulcănești – Reni;
    - Vulcănești – Kosa;
    - Vulcănești – Bolgrad (circuit 1);

- Vulcănești – Bolgrad (circuit 2);
- Vulcănești – Bolgrad (circuit 3);
- CERS Moldova – Belyaevka;
- CERS Moldova – Rozdil;
- CERS Moldova Starokazachye;
- Vasilevik – Kr. Okni;
- Brich – Dnistrovska HPP;
- Otaci – Namiya;
- Ocnița – Shahta;
- Soroca – Poroghi;
- Larga – Nelypivtsy.

\- *4 (four) 110 kV overhead line for cross-border interconnection with Romania (commercial exchanges):*

- Cioara – Huși;
- Ungheni – Țuțora;
- Gotești – Fălciu;
- Costești – Stânca.

Figure 2. National Power Grid

3. Analysis of the Power System

3.1. Identification of critical infrastructures

Table 1 lists the identified critical infrastructures within the Power System

Table 1. Critical Power Infrastructures

Operator	Name of Critical Power Infrastructures	Type
Moldelectrica	Power substation 400 kV Vulcănești	European
	Power substation 400/330 kV CERS Moldova	European
	Power substation 330 kV Răbnița	European
	Power substation 330 kV Bălți	European
	Power substation 330 kV Chișinău	National
	Power substation 330 kV Strășeni	National
	OHL 400 kV Vulcănești – Isaccea	European
	OHL 400 kV Vulcănești – CERS Moldova	National
	OHL 330 kV CERS Moldova – Novoodeska	European
	OHL 330 kV CERS Moldova – Usatove	European
	OHL 330 kV CERS Moldova – Podilska	European
	OHL 330 kV CERS Moldova – Artsyz	European
	OHL 330 kV Răbnița – Podilska (circuit 1)	European
	OHL 330 kV Răbnița – Podilska (circuit 2)	European
	OHL 330 kV Bălți – Dnistrovska HPP	European
	OHL 330 kV CERS Moldova – Chișinău (1)	National
	OHL 330 kV CERS Moldova – Chișinău (2)	National
	OHL 330 kV Chișinău – Strășeni	National
	OHL 330 kV Strășeni – Bălți	National

3.2. Identifying vulnerabilities

Table 2 lists the identified vulnerabilities within the Power System.

Table 2. Identifying vulnerabilities

No.	Identifying vulnerabilities
1.	Dependence on IPS/UPS, the Power System of the Russian Federation, with the following component countries: Belarus, Ukraine, Kazakhstan, Georgia, Mongolia, Kyrgyzstan, Azerbaijan, Tajikistan → *Using electricity as a possible energy weapon or pressure instrument for the purpose of profitability or blackmail.*

No.	Identifying vulnerabilities
2.	Electricity transmission voltage at 330 kV (atypical European Union), which is specific only to IPS/UPS, which creates dependence on this power system and makes it almost impossible to connect to another power system (ex. ENTSO-E) → *Using atypical energy transmission voltage as a possible energy weapon or pressure instrument for profitability or blackmail.*
3.	Radial distribution of the only energy main line (power grid) at 330 kV CERS Moldova – Chisinau – Straseni – Balti → *Possibility of power interruption in case of a terrorist attack or natural disaster on a critical infrastructure in this power chain (power substation or overhead line).*
4.	Lack of critical power infrastructure (power substations and overhead lines) at 400 kV [exception: 400 kV Vulcanesti and CERS Moldova power substations and 400 kV Isaccea (Romania) – Vulcanesti and Vulcanesti – CERS Moldova overhead lines] → *Impossibility of interconnector to ENTSO-E.*
5.	No international interconnection at 400 kV voltage in the north and center area with the European ENTSO-E system (Romania) → *Impossibility of interconnection to the European ENTSO-E.*

4. Proposed measures in the context of interconnection to ENTSO - E and ensuring energy security and national security

1. Appointment of a Security Liaison Officer for each critical infrastructure and elaboration of the Security Plan to the critical infrastructure operator.

Argument: Mandatory transposition of the provisions of Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection; [4]

2. The resilience of the power system in the event of terrorist attack, natural disaster or major technical failure, an important factor in ensuring energy and national security.

Argument: Resilience has become an indicator of the European Union's security policy, and in this regard the European Commission has developed the Action Plan for resilience in crisis countries 2013-2020, thus: a new approach has been reached to the societal dimension of national and european security, focusing on the citizen, community and population of a state or region;

3. Construction of national critical infrastructure:

Table 3. Construction of natural critical infrastructures

Infrastructure	Argument
a. construction of OHL 400 kV Vulcanesti – Chisinau.	Power supply security at 400 kV voltage.
b. transition of OHL 330 kV CERS Moldova – Chisinau to a voltage of 400 kV.	Power supply security at 400 kV voltage. Possibility of multiple international connection with ENTSO-E.
c. transition of OHL 330 kV Chișinău – Strășeni to a voltage of 400 kV.	
d. transition of OHL 330 kV Strășeni – Bălți to a voltage of 400 kV.	
e. construction of OHL 400 kV Strășeni – Răbnița.	Closing the 400 kV ring in the area of Răbnița, Straseni, Balti → security in the power supply at the voltage of 400 kV.
f. construction of OHL 400 kV Bălți – Răbnița.	

4. Construction of european critical infrastructure:

Table 4. Construction of european critical infrastructures

Infrastructure	Argument
a. construction of OHL 400 kV Vulcanesti – Smârdan (Romania).	Closing the 400 kV ring in the area of Vulcanesti, Isaccea (Romania), Smârdan (Romania) → Security in the power supply at the voltage of 400 kV. 400 kV system stability – ENTSO-E.
b. construction of OHL 400 kV Chisinau – Iași Fai (Romania) under the condition OHL 220 kV Suceava – Iași Fai pass to the voltage of 400 kV, or construction of OHL 400 kV Chisinau – Roman Nord.	Security in the power supply at the voltage of 400 kV. Possibility of interconnection at 400 kV voltage to ENTSO-E.
c. construction of OHL 400 kV Balti – Suceava (Romania) under the condition of construction OHL 400 kV Suceava (Romania) – Gădălin (Romania).	Security in the power supply at the voltage of 400 kV. Possibility of interconnection at 400 kV voltage to ENTSO-E.

Infrastructure	Argument
d. passing OHL 330 kV Rabnita – Podilska (Ukraine) at the voltage of 400 kV.	Possibility of interconnection at 400 kV voltage of Ukrainian power system. System stability of 400 kV.
e. passing OHL 330 kV CERS Moldova – Podilska (Ukraine) at voltage of 400 kV.	Possibility of interconnection at 400 kV voltage of Ukrainian power system. Closing of the 400 kV ring in the area of CERS Moldova, Chisinau, Straseni, Rabnita, Podilska (Ukraine), CERS Moldova → Security in electricity supply at 400 kV between the Republic of Moldova and Ukraine.
f. passing OHL 330 kV Bălți – Dnistrovska HPP (Ukraine) at voltage of 400 kV.	Possibility of interconnection at 400 kV voltage of Ukrainian power system. Closing of the 400 kV ring in Balti area, Suceava (Romania), Dnistrovska HPP (Ukraine) → Security in electricity supply at 400 kV voltage between the Republic of Moldova and Ukraine.

5. Construction of power plants:

Table 5. Construction of power plants

Infrastructure	Argument
a. construction of hydroelectric power plants on the Prut River	energy independence. energy stability. trade in electricity. energy security.
b. construction of hydroelectric power plants on the Nistru River	
c. construction of nuclear power plants	
d. construction of power plants based on renewable energy sources, biomass, or other energy sources.	

5. Conclusion

Considering that there are strong cooperation relations between Romania and the Republic of Moldova, we must be integrated into the same power system and especially have the same solid principles regarding the area energy security, where the Black Sea plays an increasingly crucial and strategic role. In this context, Romania provides governmental aid on the integration of the Republic of Moldova into the European Union and consistent support on the interconnection to the ENTSO-E energy system. In this paper, the authors came up with a series of proposals on different ways of interconnection to ENTSO-E and ensuring the stability and security of the Moldovan energy system. These proposals for measures consist mainly of major investments in energy infrastructure, such as:

- construction of hydroelectric power plants on the Prut and Nistru rivers, nuclear power plants, power plants based on renewable energy sources, or other energy sources, which will ensure the electricity needs for the Republic of Moldova to become an energy independent state;
- the construction of power substations at 400 kV voltage which will ensure the transit of electricity and its transformation to different voltages of household, industrial and especially critical consumers;
- the construction of overhead lines at a voltage of 400 kV which will ensure the interconnections between the Moldovan energy system and ENTSO-E.

The investments are major because Moldova is dependent on the Russian power system operating at the atypical voltage of 330 kV, and this can be easily used as an energy weapon or pressure instrument. Following these investments, of course with the help of Romania and the European Union, Moldova will become a credible, strategic and energy-secure partner state of the European Union.

References

[1] ENTSO-E, www.entsoe.eu
[2] Moldelectrica, www.moldelectrica.md
[3] Fîță N.D., Radu S.M., Păsculescu D., Gregory E., Ranf D.E., Bucovetchi O.M.C., Badea D., (Coordinators), *Sustainability Management and managerial sustainability between classical and modern paradigms, chapter: Addressing national critical energy infrastructures correlated with societal resilience and sustainability*, "Nicolae Bălcescu" Academy of Land Forces Publishing House, Sibiu, 2021, p.p. 37 – 58.
[4] Council Directive 2008/114/EC of 8 December 2008 on the identification and designation of European critical infrastructures and the assessment of the need to improve their protection.

[5] Government of the Republic of Moldova, Decision no. HG701/2018 of 11.07.2018, for the approval of the Regulation on the anti-terrorist protection of critical infrastructure.
[6] Fîță N.D., Radu S.M., Păsculescu D., *Ensuring, controlling and stability of energy security in the context of increasing industrial and national security*, Universitas Publishing House, Petrosani. 2021.
[7] Fîță N.D., *Identifying the vulnerabilities of critical infrastructures within the national electricity system in the context of increasing energy security*, Universitas Publishing House, Petrosani, 2019.
[8] Fîță N.D., Păsculescu D., Pupăza C., Gregory E., *Methodology for identification, designation, analysis, evaluation, protection and resilience of critical electroenergy infrastructures. In resilience Management in Contemporary society,* Bucovetchi O.M.C., Ranf D.E., (Coordinators): „Nicolae Bălcescu" Academy of Land Forces Publishing House, Sibiu, 2022, pp. 180-201.
[9] Romanian Intelligence Service, www.sri.ro

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