

Energy security aspects related to the National Power Grid

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Abstract. National Power Grid is an important element within the National Power System, having in its composition critical infrastructures of national importance without which the national economy could not operate, and its non-operation, totally or partially (black/brown-out), generates energy insecurity, negative factor with devastating and catastrophic effects on industrial, economic and national security. Due to the fact that National Power Grid is of national strategic importance, it has to be assessed and monitored permanently in terms of security risks, in order to identify vulnerabilities, and this need for assessment also comes from the European perspective because Romania is interconnected to ENTSO-E (European Network of Transmission System Operators) which interconnects various power overhead lines from North to South, from West to East, or even with Africa and Asia. In order to secure the National Power Grid, the authors have set out in this paper to identify possible internal or external vulnerabilities and what impact they have on the National Power Grid and National Power System. By knowing the vulnerabilities, one can automatically identify the dangers and threats to which it is subjected and engaged, being able to develop national/European measures or strategies for the protection and security of the critical infrastructures related to. For this reason, it is considered that the identification of vulnerabilities must become a pressing issue of national, and European energy security and be a useful tool for authorities to develop a energy strategy (short – long term) for the proper functioning of the National Power Grid and the national economy, because all sectors of the economy depend on electricity. The identified vulnerabilities are eliminated by *National Energy Strategy 2021 – 2036* (short, medium, and long term) proposed by the authors, with the aim of increasing energy and national security.

1 General information regarding energy security

As we know, while we are facing an increase for the cases of energy collapses around the world, although this is manifested by the lack of electricity (phenomenon described by black-out) in industrial and household consumers, makes this paper of great importance and relevance, knowing that there are critical power infrastructure that can be vulnerable to some several internal or even external factors [1-3]. The lack of electricity supply to industrial and

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household consumers leads to national crises that cause a state of societal imbalance causing extreme damage to the safety of citizens, industry, the national economy and thus national security, because all sectors of a national economy depend on electricity. In this context, the National Power System - NPS, through the National Power Grid – NPG, becomes a strategic objective of national importance by generating national and European critical infrastructures, without which the national economy cannot function properly [4-6]. *Romania's energy security depends on the energy independence in the context of the sustainable development of the European Union, therefore the energetic stability factors must be created by: providing the necessary primary resources (natural gas, oil, coal, uranium, etc.) for the engendering of electricity and therefore limiting the dependence on imports; enlarging provided natural resources considering the import for producing electrical energy and by its ways for the distribution; increasing the adequacy and safety of national transmission networks for electricity and gas outages; protection of the critical infrastructure regarding the physical integrity of energy purposes; securing workplaces and personnel by avoiding and/or stopping technical accidents/ incidents that could lead to disruption of the NPS [7-9].*

But Romania's energy security is endangered by various elements of instability that may threaten the safety and security of NPG: *vulnerabilities* (natural and anthropogenic hazards); *threats* (terrorist acts, political instability, armed conflict and piracy); *dangers* (lack of supply of raw materials necessary for the production of electricity, use of electricity as a weapon or pressure tool, high costs of electricity, etc.)[10].

In order to stabilize and increase energy security, the NPG must be constantly subject to security assessments to identify vulnerabilities, risks, dangers or threats, in order to prevent, combat or eliminate these sources of instability that may lead to NPS insecurity and general insecurity, and the recommendation is that these identification and evaluation processes be carried out more preventively than corrective [11].

2 Description of the NPG

The NPG infrastructure is as follows, according to Figure 1:

- **81 power substations**, from which: 1 power substation of 750 kV; 38 power substations of 400 kV; 42 power substations of 220 kV;
- **8931.6 km overhead power lines - OHL**, from which: 154,6 km. – 750 kV; 4703,7 km. – 400 kV; 4035,2 km. – 220 kV;
- **218 distribution units** totalling 37794 MVA [12-14].

Table 1. Power substations within NPG

POWER SUBSTATIONS		
750 kV	400 kV	220 kV
750/400 kV Isaccea*	400/220/110 kV South Bucharest; 400/110 kV Domnești; 400/220/110 kV Iernut; 400/220/110 kV South Sibiu; 400/110 kV Dârste; 400/110 kV Brașov; 400/220/110 kV Gutinaș; 400/220/110 kV Suceava; 400/110 kV South Bacău; 400/110 kV North Roman; 400 kV Stupina; 400 kV Rahman; 400/220/110 kV Lacu Sărat;	220/110 kV Fundeni; 220/110 kV Gheorgheni; 220/110 kV Fântânele; 220/110 kV Ungheni; 220/110 kV Alba Iulia; 220/110 kV Munteni; 220/110 kV Iași (FAI); 220/110 kV Dumbrava; 220/110 kV Stejaru; 220/110 kV Filești; 220/110 kV Bărboși; 220/110 kV West Focșani; 220/110 kV Stâlpu; 220/110 kV Teleajen;

	400 kV Cernavodă; 400/110 kV South Medgidia; 400/110 kV North Constanța; 400/110 kV Tariverde; 400/110 kV West Tulcea; 400/110 kV Smârdan; 400/220/110 kV West Brazi; 400/220/110 kV Bradu; 400/110 kV Gura Ialomiței; 400/110 kV Pelicanu; 400 kV Țânțăreni (Bulgaria); 400 kV Porțile de Fier (Serbia); 400/220/110 kV Urechești; 400/220 kV Slatina; 400/110 kV Drăgănești-Olt; 400/220/110 kV Arad (Hungary); 400 kV Nădab (Hungary); 400 kV Reșița (Serbia); 400/220/110 kV Mintia; 400/220 kV Roșiori (Ukraine); 400 kV Gădălin; 400/110 kV East Cluj; 400/110 kV South Oradea;	220/110 kV Mostiștea; 220/110 kV Turnu Măgurele; 220/110 kV Ghizdaru; 220/110 kV Târgoviște; 220/110 kV South Pitești; 220/110 kV Arefu; 220/110 kV Stupărei; 220/110 kV North Târgu-Jiu; 220/110 kV Sărdănești; 220/110 kV Turnu Severin; 220/110 kV Cetate; 220/110 kV Calafat; 220/110 kV Grădiște; 220/110 kV North Craiova; 220/110 kV Răureni; 220/110 kV Calea Aradului; 220/110 kV Reșița (Serbia); 220/110 kV Săcălaz; 220/110 kV Timișoara; 220/110 kV Iaz; 220/110 kV Peștiș; 220/110 kV Hășdat; 220/110/20 kV Baru Mare; 220/110 kV Paroșeni. 220/110 kV Câmpia Turzii; 220/110 kV Cluj, Florești; 220/110 kV Tihău; 220/110 kV Sălaj; 220/110 kV Baia Mare 3; 220/110 kV Vetis.
* operates at a voltage of 400 kV.		

Table 2. Power overhead lines within NPG

POWER OVERHEAD LINES	
OHL 750 kV	
750 kV Isaccea – South Ukraine (Ukraine) – disused OHLpla;	
750 kV Isaccea – Stupina (Romania) – operates at a voltage of 400 kV;	
750 kV Stupina – Varna (Bulgaria) – operates at a voltage of 400 kV.	
OHL 400 kV	OHL 220 kV
400 kV South Bucharest – Domnești;	220 kV South Bucharest – Fundeni;
400 kV South Bucharest – Gura Ialomiței;	220 kV South Bucharest – Ghizdaru;
400 kV South Bucharest – Pelicanu;	220 kV South Bucharest – Mostiștea;
400 kV South Bucharest – Slatina;	220 kV Fundeni – West Brazi;
400 kV Domnești – West Brazi;	220 kV Gheorgheni – CHE Stejaru;
400 kV Iernut – Gădălin;	220 kV Gheorgheni – Fântânele;
400 kV Iernut – South Sibiu;	220 kV Fântânele – Ungheni;
400 kV South Sibiu – Mintia;	220 kV Ungheni – Iernut;
400 kV South Sibiu – Țânțăreni;	220 kV Iernut – Baia Mare 3;
400 kV South Sibiu – Brașov;	220 kV Iernut – Câmpia Turzii;
400 kV Brașov – Bradu;	220 kV South Sibiu – CHE Lotru;
400 kV Brașov – Dârste;	220 kV Alba Iulia – Mintia;
400 kV Brașov – Gutinaș;	220 kV Alba Iulia – CHE Șugag;
400 kV Dârste – West Brazi;	220 kV Alba Iulia – CHE Gâlceag;
400 kV Gutinaș – Brașov;	220 kV Alba Iulia – Cluj Florești.
400 kV Gutinaș – South Bacău;	220 kV Gutinaș – Dumbrava;
400 kV Bacău South – North Roman;	220 kV Gutinaș – CTE Borzești;
400 kV Roman North – Suceava;	220 kV Gutinaș – Munteni;

400 kV Rahman – Dobrudja (Bulgaria);	220 kV Gutinaș – Iași (FAI);
400 kV Isaccea – Vulcănești (Rep. Moldova);	220 kV Iași (FAI) – Munteni;
400 kV Smârdan - Gutinaș;	220 kV Iași (FAI) – Suceava;
400 kV Smârdan – Lacu Sărat;	220 kV Dumbrava – CHE Stejaru;
400 kV Smârdan - Isaccea;	220 kV CHE Stejaru – Gheorgheni.
400 kV Lacu Sărat – Gura Ialomiței;	220 kV West Focșani – Gutinaș;
400 kV Lacu Sărat – Isaccea;	220 kV West Focșani – Bărboși;
400 kV Isaccea – West Tulcea;	220 kV Bărboși – Filești;
400 kV Isaccea – Rahman;	220 kV Lacu Sărat – CTE Brăila;
400 kV Tulcea West – Tariverde;	220 kV Teleajen – West Brazi;
400 kV Tariverde – North Constanța;	220 kV Teleajen – Stâlpu;
400 kV North Constanța – Cernavodă;	220 kV Mostiștea – South Bucharest;
400 kV Cernavodă – Medgidia South;	220 kV Turnu Măgurele – Ghizdaru;
400 kV Cernavodă – Pelicanu;	220 kV Turnu Măgurele – North Craiova;
400 kV Cernavodă – Gura Ialomiței;	220 kV Ghizdaru – South Bucharest;
400 kV Lacu Sărat – CTE Brăila;	220 kV Târgoviște – West Brazi;
400 kV West Brazi - Dârste;	220 kV Târgoviște – Bradu;
400 kV West Brazi – CTE Petrom Brazi;	220 kV South Pitești – Bradu;
400 kV West Brazi - Domnești;	220 kV Arefu – CHE Vidraru;
400 kV Bradu - Brașov;	220 kV Arefu – Răureni;
400 kV Bradu - Țânțăreni;	220 kV Bradu – Stupărei.
400 kV Gura Ialomiței – Lacu Sărac;	220 kV Urechești – North Târgu Jiu;
400 kV Gura Ialomiței – Cernavodă;	220 kV Urechești – Sărdănești;
400 kV Gura Ialomiței – Bucharest South;	220 kV Sărdănești – North Craiova;
400 kV Pelicanu – Cernavodă;	220 kV North Craiova – Slatina;
400 kV Pelicanu – South Bucharest;	220 kV North Craiova – Turnu Măgurele;
400 kV Porțile de Fier – Djerdap (Serbia);	220 kV CTE Ișalnița – Grădiște;
400 kV Țânțăreni – Kosloduy (Bulgaria);	220 kV Grădiște – Slatina;
400 kV Urechești – Porțile de Fier;	220 kV Porțile de Fier – Reșița;
400 kV Urechești – Domnești;	220 kV Porțile de Fier – Turnu Severin;
400 kV Urechești – Țânțăreni;	220 kV Porțile de Fier – Cetate;
400 kV Urechești – CTE Rovinari;	220 kV Cetate – Calafat;
400 kV Porțile de Fier - Slatina;	220 kV Răureni – Arefu;
400 kV Țânțăreni – Bradu;	220 kV Răureni – Stupărei;
400 kV Țânțăreni – Slatina;	220 kV Stupărei – Bradu;
400 kV Țânțăreni – CTE Turceni;	220 kV North Craiova – CTE Ișalnița;
400 kV Slatina – South Bucharest;	220 kV CHE Lotru – South Sibiu.
400 kV Slatina – Drăgănești-Olt;	220 kV Arad – Calea Aradului;
400 kV Nădab – Bekecsaba (Hungary);	220 kV Arad – Timișoara;
400 kV Arad – Sandorfalva (Hungary);	220 kV Calea Aradului – Săcălăz;
400 kV Reșița – Pancevo (Serbia);	220 kV Săcălăz – Timișoara;
400 kV Nădab – Arad;	220 kV Timișoara – Mintia;
400 kV Arad – Mintia;	220 kV Timișoara – Reșița;
400 kV Mintia – South Sibiu;	220 kV Reșița – Iaz;
400 kV Roșiori – Mukacevo (Ukraine);	220 kV Reșița – Porțile de Fier;
400 kV Roșiori – South Oradea;	220 kV Mintia – Pestiș;
400 kV Roșiori – Gădălin;	220 kV Mintia – Hășdat;
400 kV Gădălin – East Cluj;	220 kV Mintia – Alba Iulia;
400 kV Gădălin – Iernut.	220 kV Hășdat – Pestiș;
	220 kV Hășdat – CHE Retezat;
	220 kV Hășdat – Baru Mare;
	220 kV Baru Mare – Paroșeni;
	220 kV Paroșeni – North Târgu Jiu;
	220 kV Roșiori – Vetîș;
	220 kV Roșiori – Baia Mare 3;
	220 kV Baia Mare 3 - Tihău;
	220 kV Baia Mare 3 - Iernut;

	220 kV Tihău - Sălaj; 220 kV Tihău – Cluj, Florești; 220 kV Cluj, Florești – CHE Mărișelu; 220 kV Cluj, Florești – Câmpia Turzii; 220 kV Cluj, Florești – Alba Iulia; 220 kV Câmpia Turzii – Iernut.
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Table 3. Power plant within NPG

POWER PLANT
Thermal power plant South Bucharest – 270 MW (eviction of 400 kV);
Thermal power plant Iernut – 563 MW (eviction of 400 kV);
Hydro power plant Șugag – 149 MW (eviction of 220 kV);
Hydro power plant Gâlceag – 149 MW (eviction of 220 kV);
Hydro power plant Stejaru – 143 MW (eviction of 220 kV);
Thermal power plant Borzești – 210 MW (eviction of 220 kV);
Nuclear power plant Cernavodă – 1300 MW (eviction of 400 kV);
Eolian power plant Stupina – 278 MW (eviction of 110 kV);
Eolian power plant Rahman – 242 MW (eviction of 110 kV);
Thermal power plant Brăila – 210 MW (eviction of 400 kV);
Thermal power plant Petrom Brazi – 850 MW (eviction of 400 kV);
Eolian power plant Făcăeni – 132 MW (eviction of 400 kV);
Hydro power plant Vidraru – 219 MW (eviction of 220 kV);
Hydro power plant Porțile de Fier – 1080 MW (eviction of 400 kV);
Thermal power plant Turceni – 1196 MW (eviction of 400 kV);
Thermal power plant Rovinari – 888 MW (eviction of 400 kV);
Thermal power plant Ișalnița – 582 MW (eviction of 220 kV);
Hydro power plant Lotru – 509 MW (eviction of 220 kV);
Thermal power plant Mintia – 930 MW (eviction of 400 kV);
Thermal power plant Paroșeni – 133 MW (eviction of 220 kV);
Hydro power plant Retezat – 210 MW (eviction of 220 kV);
Hydro power plant Mărișelu – 215 MW (eviction of 220 kV).

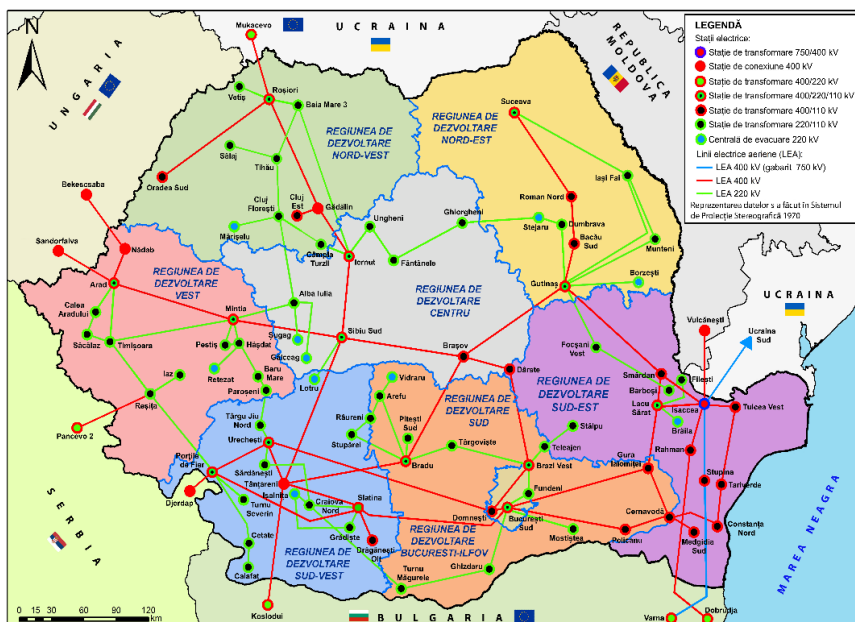


Fig. 1. NPG map (map’s legend is presented in Romanian)

Table 4. Cross-border power infrastructures within NPG

POWERS SUBSTATIONS	POWER OVERHEAD LINES
750 kV Isaccea* → Ukraine and Moldova; 400 kV Stupina** → Bulgaria; 400 kV Rahman → Bulgaria; 400 kV Țânțăreni → Bulgaria; 400 kV Porțile de Fier → Serbia; 400 kV Reșița → Serbia; 400/220/110 kV Arad → Hungary; 400 kV Nădab → Hungary; 400/220 kV Roșiori → North Ukraine.	750 kV Isaccea* → South Ukraine (South Ukraine); 750 kV Stupina** → Varna (Bulgaria); 400 kV Isaccea → Vulcănești (Rep. Moldova); 400 kV Rahman → Dobruđa (Bulgaria); 400 kV Țânțăreni → Kosloduy (Bulgaria); 400 kV Porțile de Fier → Djerdap (Serbia); 400 kV Reșița → Pancevo (Serbia); 400 kV Arad → Sandorfalva (Hungary); 400 kV Nădab → Bekescsaba (Hungary); 400 kV Roșiori → Mukacevo (North Ukraine).
* operates at a voltage of 400 kV; ** gabarit of 750 kV;	* disused lines; ** operates at a voltage of 400 kV;

3 Measures and proposals concerning the operational security of NPG and increasing energy security

3.1 Identifying vulnerabilities

a) Internal vulnerabilities with internal impact within NPG, according to the table 5.

Table 5. Internal vulnerabilities with internal impact within NPG

INTERNAL VULNERABILITIES WITH INTERNAL IMPACT WITHIN NPG	
1.	<i>Development region for BUCHAREST – ILFOV:</i> Failure to close the 400 kV ring in the area of Bucharest and Ilfov County (South Bucharest – Domnești – West Brazi – Fundeni – South Bucharest).
2.	<i>Development region for CENTER:</i> Failure to close the 400 kV ring in the northern and western areas of the North-East region (Iernut – South Sibiu – Brașov – Gutinaș – Dumbrava – Stejaru – Gheorgheni – Fântânele – Ungheni – Iernut).
3.	<i>Development region for NORTH – EAST:</i> Failure to close the 400 kV ring in the north-est areas of the North-East region (Gutinaș – Munteni – Iași FAI – Suceava).
4.	<i>Development region for NORTH – EAST:</i> 400 kV radial distribution Gutinas - Suceava (Gutinaș – South Bacău – North Roman – Suceava).
5.	<i>Development region for SOUTH – EAST:</i> Failure to close the 400 kV ring in the northern part of the South-East region (Lacu Sărat – Filești – Bărboși – West Focșani – Gutinaș).
6.	<i>Development region for SOUTH – EAST:</i> Missing the european interconnection between 400 kV Sandorfalva – Arad and 400 kV Cernavodă power plant (Sandorfalva – Arad – Mintia – South Sibiu – Brașov – Dârste) – (Dârste – Stâlpu – Gura Ialomiței – Cernavodă).
7.	<i>Development region for SOUTH:</i> Failure to close the 400 kV ring in the central area of the South region (West Brazi – Târgoviște – Bradu – Brașov – Dârste – West Brazi).
8.	<i>Development region for SOUTH:</i> Failure closing for the 400 kV ring (or doubling the ring) in the southern part of the South region and the southern part of the South-West region (South Bucharest – Ghizdaru – Turnu Măgurele) and (Turnu Măgurele – North Craiova – Sărdănești – Urechești).
9.	<i>Development region for SOUTH – WEST:</i>

	Failure closing for the 400 kV ring (or doubling the ring) in the southern part of the South-West region and the southern part of the South region (Turnu Măgurele – North Craiova – Sărdănești – Urechești) and (South Bucharest – Ghizdaru – Turnu Măgurele).
10.	<i>Development region for WEST:</i> Failure to close the 400 kV ring in the western part of the Western region (Arad – Calea Aradului – Săcălaz – Timișoara).
11.	<i>Development region for WEST:</i> Failure to close the 400 kV ring in the central area of the West region (Arad – Mintia – Timișoara).
12.	<i>Development region for WEST:</i> Failure to close the 400 kV ring in the eastern part of the Western region (Mintia – Hășdat – Baru Mare – Paroșeni – Târgu Jiu Nord – Urechești) and (Urechești – Porțile de Fier – Reșița – Timișoara – Arad – Mintia).
13.	<i>Development region for WEST:</i> Failure to close the 400 kV ring in the eastern part of the Western region (Mintia – Hășdat – Pestiș).
<i>LEGEND:</i> <i>Red color: Power Critical Infrastructures (power substation and OHL) for 400 kV;</i> <i>Green color: Power Critical Infrastructures (power substation and OHL) 220 kV.</i>	

b) External vulnerabilities with external impact within NPG, according to the table 6.

Table 6. External vulnerabilities with external impact within NPG

EXTERNAL VULNERABILITIES WITH EXTERNAL IMPACT WITHIN NPG	
1.	<i>Development region for NORTH – EAST:</i> Missing the international interconnection voltage of 400 kV in the North of North - West and North - East Romania (Suceava – Bălți).
2.	<i>Development region for NORTH – EAST:</i> Failure to close the 400 kV ring in the northern part of Romania (Suceava – Roșiori) or (Suceava – Gădălin).
3.	<i>Development region for WEST:</i> Failure to close the 400 kV ring in the western part of the Western region and Romania (Arad – Timișoara – Reșița – Porțile de Fier).
4.	<i>Development region for NORTH – WEST:</i> Failure to close the 400 kV ring in the western part of the western region and Romania (South Oradea – Nădab).
<i>LEGEND:</i> <i>Red color: Power Critical Infrastructures (power substation and OHL) for 400 kV;</i> <i>Green color: Power Critical Infrastructures (power substation and OHL) 220 kV.</i>	

c) External vulnerabilities within neighbouring power systems with internal impact on NPG, according to the table 7 [15].

Table 7. External vulnerabilities within neighbouring power systems with internal impact on NPG

EXTERNAL VULNERABILITIES WITHIN NEIGHBOURING POWER SYSTEM WITH INTERNAL IMPACT ON NPG	
1.	<i>REPUBLIC OF MOLDOVA:</i> Total dependence to the IPS (Integrated Power System) Power System of the former Soviet Union countries following components: Belarus, Ukraine, Moldova, Kazakhstan, Georgia, Mongolia, Kyrgyzstan, Azerbaijan, Tajikistan (power weapon or pressure tool).
2.	<i>REPUBLIC OF MOLDOVA:</i> The voltage of 330 kV (atypical EU) which is specific only to IPS (Integrated Power System), which creates dependence on this power system and makes it almost impossible to interconnect to another power system (eg Romanian EEA), without major investments in power infrastructure power stations, overhead power lines and power plants) (power weapon or pressure tool).

3.	<i>REPUBLIC OF MOLDOVA:</i> The single radial distribution bus of energy (HV-OHL) voltage of 330 kV (atypical EU) [CERS Moldova – Chişinău – Străşeni – Bălţi – Dnistrovka (Ukraine)].
	<i>REPUBLIC OF MOLDOVA:</i> Total absence (except the ESRB 400 kV and the 400 kV Vulcanesti Moldova - Moldova ESRB) Power Critical Infrastructure (substations and overhead lines) at a line voltage of 400 kV [ES 330 kV Chişinău, ES 330 kV Străşeni, ES 330 kV Bălţi, OHL 330 kV CERS Moldova – Chişinău, OHL 330 kV Chişinău – Străşeni, OHL 330 kV Străşeni – Bălţi, OHL 330 kV Bălţi – Dnistrivska (Ukraine)].
5.	<i>REPUVA:</i> Missing the international interconnection voltage of 400 kV in the north of Moldova (OHL Bălţi – Suceava, OHL Chişinău – Munteni, OHL Străşeni – Iaşi FAI).
6.	<i>UKRAINE:</i> Total dependence to the IPS (Integrated Power System) Power System of the former Soviet Union countries following components: Belarus, Ukraine, Moldova, Kazakhstan, Georgia, Mongolia, Kyrgyzstan, Azerbaijan, Tajikistan (power weapon or pressure tool).
7.	<i>UKRAINE:</i> The voltage of 330 to 750 kV (atypical EU) which is peculiar to IPS (Integrated Power System), which creates the dependency on the power system and make it almost impossible for interconnection to other power system (eg EEA Romanian, Slovak, Polish), with major investments in power infrastructure (power stations, overhead power lines and power plants) (power weapon or pressure tool).
8.	<i>UKRAINE:</i> Loop radial distribution of energy bus (HV-OHL) voltage of 330 kV (atypical EU) [Bălţi (Republica Moldova) – Dnistrovka – Kamianetsk-Podilska – Chernivetska – Ivano-Frankivst – Burshtyn].
9.	<i>UKRAINE:</i> Total absence (except Mukacevo 400 kV and 400 kV Donbaska and Roşiori-Mukacevo) Power Critical Infrastructure (power substations and overhead lines) at a voltage of 400 kV [ES 330 kV Dnistrovka, ES 330 kV Kamianetsk-Podilska, ES 330 kV Chernivetska, ES 330 kV Ivano-Frankivst , OHL 330 kV Bălţi – Dnitrovka, OHL 330 kV Dnitrovka – Kamianetsk-Podilska, OHL 330 kV Kamianetsk-Podilska – Ivano-Frankvist, OHL 330 kV Ivano-Frankvist – Burshtyn].
<i>LEGEND:</i> Red color: Power Critical Infrastructures (power substation and OHL) for 400 kV; Green color: Power Critical Infrastructures (power substation and OHL) 220 kV. Purple color: Power Critical Infrastructures (power substation and OHL) 330 kV.	

3.2 Drawing up the National Energy Strategy 2021 – 2036

The National Energy Strategy (short, medium and long term) following proposed solutions by the authors to eliminate (combat) the internal or external vulnerabilities of the NPG, according to the table 8.

Table 8. National Energy Strategy 2021 – 2036 (short, medium and long term)

		Importance I (Important) VI (Very Important) U (Urgently)	Period / Term S – Short (1 – 5 years) M – Medium (5 – 10 years) L – Long (10 – 15 years)
THE SOLUTIONS REGARDING THE ELIMINATION OF INTERNAL OR EXTERNAL VULNERABILITY OF NPG			
1	1.1. Passing OHL 220 kV Bucureşti Sud – Fundeni to 400 kV voltage	VI	M

	1.2. Passing OHL 220 kV Fundeni – West Brazi to 400 kV voltage		
	1.3. Passing PS 220 kV Fundeni to 400 kV voltage		
2	2.1. Passing OHL 220 kV Iernut – Ungheni – Fântânele – Gheorgheni – Stejaru – Dumbrava – Gutinaș to 400 kV voltage	VI	M
	2.2. Passing PS 220 kV Ungheni, Fântânele, Gheorgheni, Stejaru, Dumbrava to 400 kV voltage		
3	3.1. Passing OHL 220 kV Gutinaș – Munteni – Iași (FAI) – Suceava to 400 kV voltage	VI	M
	3.2. Passing OHL 220 kV Gutinaș – Iași (FAI) to 400 kV voltage		
	3.3. Passing PS 220 kV Munteni, Iași (FAI) to 400 kV voltage		
4	4.1. The construction of a OHL 400 kV to double the power supply to the OHL Suceava – Gutinaș, also serving to close the 400 kV ring in the northern part of the country. There are 2 possibilities: - <i>the construction OHL 400 kV Gădălin – Suceava at 400 kV voltage;</i> - <i>the construction OHL 400 kV Roșiori – Suceava at 400 kV voltage.</i>	U	S
5	5.1. Passing OHL 220 kV Lacu Sărat – Filești – Bărboși – Focșani Vest – Gutinaș to 400 kV voltage	VI	M
	5.2. Passing PS 220 kV Focșani Vest, Bărboși, Filești to 400 kV voltage		
6	6.1. The construction of a OHL 400 kV for the interconnection of the European bus 400 kV Sandorfalva – Arad with the 400 kV Cernavoda power substation. There are 2 possibilities: - <i>the construction OHL 400 kV Dârste – Stâlpu – Gura Ialomiței;</i> - <i>the construction OHL 400 kV Brașov – Stâlpu – Cernavoda.</i>	VI	M
	6.2. Passing OHL 220 kV Brazi Vest – Teleajen – Stâlpu to 400 kV voltage		
	6.3. Passing PS 220 kV Teleajen and Stâlpu to 400 kV voltage		
7	7.1. Passing OHL 220 kV Bradu – Târgoviște – Brazi Vest to 400 kV voltage	I	L
	7.2. Passing PS 220 kV Târgoviște to 400 kV voltage		
8	8.1. Passing OHL 220 kV București Sud – Ghizdaru – Turnu Măgurele to 400 kV voltage	I	L
	8.2. Passing PS 220 kV Ghizadru and Turnu Măgurele to 400 kV voltage		
	8.3. Passing OHL 220 kV București Sud – Mostiștea to 400 kV voltage		
	8.4. Passing PS 220 kV Mostiștea to 400 kV voltage		
9	9.1. Passing OHL 220 kV Turnu Măgurele – Craiova Nord – Sărdănești – Urechești to 400 kV voltage	I	L
	9.2. Passing PS 220 kV Craiova Nord and Sărdănești to 400 kV voltage		
10	10.1. Passing OHL 220 kV Timișoara – Săcălaz – Calea Aradului – Arad to 400 kV voltage	VI	M
	10.2. Passing PS 220 kV Timișoara, Săcălaz and Calea Aradului to 400 kV voltage		

11	11.1. Passing OHL 220 kV Arad – Timișoara to 400 kV voltage	VI	M
	11.2. Passing OHL 220 kV Timișoara – Mintia to 400 kV voltage		
	11.3. Passing PS 220 kV Timișoara to 400 kV		
12	12.1. Passing OHL 220 kV Mintia – Hășdat – Baru Mare – Paroșeni – Târgu Jiu Nord – Urechești to 400 kV voltage	I	L
	12.2. Passing PS 220 kV Hășdat, Baru Mare, Paroșeni and Târgu Jiu Nord to 400 kV voltage		
13	13.1. Passing OHL 220 kV Mintia – Hășdat – Pestiș to 400 kV voltage	I	L
	13.2. Passing PS 220 kV Hășdat and Pestiș to 400 kV voltage		
14	14.1. The construction OHL 400 kV Suceava – Bălți in order to connect Romania with the Republic of Moldova	U	S
15	15.1. The construction of a OHL 400 kV for interconnection between PS 400 kV Suceava with PS 400 kV Roșiori or 400 kV Gădălin. There are 2 possibilities: - <i>the construction of the OHL 400 kV Gădălin – Suceava at a voltage 400 kV;</i> - <i>the construction of the OHL 400 kV Roșiori – Suceava at a voltage of 400 kV.</i>	U	S
	16.1. Passing OHL 220 kV Porțile de Fier – Reșița – Timișoara – Arad to 400 kV voltage		
16	16.2. Passing PS 220 kV Timișoara to 400 kV voltage	U	S
	17.1. The construction of the OHL 400 kV Oradea Sud – Nădab at a voltage 400 kV;		
LEGEND: - OHL – Power Overhead Line; - PS – Power Substation.			

4. Conclusions

According to follows of the risk assessment of energy security on critical infrastructure (power substations and power overhead lines) within NPG, we have identified 26 vulnerabilities: 13 internal vulnerabilities with internal impact within NPG, 4 external vulnerabilities with external impact within NPG, and 9 external vulnerabilities within neighbouring power systems with internal impact on NPG.

The need to identify vulnerabilities of critical infrastructures in the NPG apparent from the following considerations: knowing the fact that NPG is of national strategic importance, it should be assessed and continuously monitored in terms of security risks in order to identify vulnerabilities, the need for security risk assessment comes from a European perspective because Romania is interconnected ENTSO-E (European Union power system), by knowing the vulnerabilities, we can automatically identify dangers and threats that NPG is subject engaged and create measures or national strategy to protect and secure critical infrastructures national/European, and specific risk scenarios developed a high level of risk with devastating effects on national security.

The identified vulnerabilities are eliminated by *National Energy Strategy 2021 – 2036* (short, medium, and long term) proposed by the authors, with the aim of increasing energy and national security, resulting from the following: **5 solutions: U – Urgently in S – Short Period/Term (1 – 5 years):** point 4 (4.1.); point 14 (14.1.); point 15 (15.1.); point 16 (16.1.; 16.2.); point 17 (17.1.), **7 solutions: VI – Very Important in M – Medium Period/Term (5 – 10 years):** point 1 (1.1.; 1.2.; 1.3.); point 2 (2.1.; 2.2.); point 3 (3.1.; 3.2.; 3.3.); point 5 (5.1.; 5.2.); point 6 (6.1.; 6.2.; 6.3.); point 10 (10.1.; 10.2.); point 11 (11.1.; 11.2.; 11.3.), and

5 solutions: I – Important in L – Long Period/Term (10 – 15 years): point 7 (7.1.; 7.2.); point 8 (8.1.; 8.2.; 8.3.; 8.4.); point 9 (9.1.; 9.2.); point 12 (12.1.; 12.2.); point 13 (13.1.; 13.2.).

Energy security vulnerability should be prevented, combated and eliminated through **major investments** in power infrastructure (*power substations, overhead power lines and power plant*) and **qualified personnel** in following activity regarding electrical installation high, very high and ultra high voltage: *operational, maneuvers, maintenance, dispatch, occupational health and safety, critical infrastructures protection and emergency or crisis response.*

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