Electricity transmission network development plan for 2018-2027 period

#	Elemente privind operaţiunea	Numele şi prenumele	Funcţia	Data	Semnătura
1	Aprobat	Ghennadi Dimov	Director general	26.01.18	
2	Verificat	Veaceslav Zastavneţchi	Vicedirector general	26.01.18	
3	Verificat	Valeriu Moldovan	Inginer-Şef	26.01.2018	
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Chisinau 2017

Legal framework

S.E. „Moldelectrica” is committed to elaborate a plan of electric transmission network development in the next 10 years, that will be submitted for approval to the National Energy Regulatory Agency, under the clauses of the law ,,*Electrical Energy Law* of Republic of Moldova” [1, art.34], and the *Energy Strategy of Republic of Moldova* [29].

Working team

The development plan was elaborated on the base of ,,The Elaboration of Electric Network Development Plan for the period 2018-2027” [63], that was written by the experts of the Power Engineering and Electrotechnical Department of the Technical University of Republic of Moldova, project manager *prof.dr. I. Stratan*. The whole team, that was involved in researches is presented on the page 75, paper accountable is Mr. *Iu. Cazacu*, Chief of Power System Operating Modes Department.

Approval stages

The Electric Transmission Network Development Plan within 2018-2027 was submitted for discussion on 22 November 2017.
This Plan was approved by National Energy Regulatory Agency on 27 December 2017.

SYNTHESIS

The transmission System Operator S.E. ,,Moldelectrica” is required to elaborate the plan of electric transmission network for the next 10 years, that will be submitted to National Energy Regulatory Agency. In regard to the compliance with clauses of „*Electrical Energy Law of Republic of Moldova*” [1, art.34].

The Republic of Moldova shares borders with Romania to the West, and with Ukraine to the North and East. However, their electric power systems don’t work in parallel till present. The electric power systems parallel operation between Republic of Moldova and Ukraine is performed through seven 330 kV OHLs and eleven 110 kV OHLs, while islanded operation of the electric power systems of Romania and Republic of Moldova is performed through one 400 kV OHL Vulcanesti – Isaccea and four 110 kV OHL.

The perspective of electric power systems development of neighbor’s countries was considered when elaborating the development plan of Moldova’s electric transmission network as such development plans have been already prepared for those countries.

The development plan structures differ for TSO of Romania [2] and Ukraine [3] as Ukraine firstly achieved this goal in 2016, while Romania has been actualizing it repeatedly.

The following peculiarities were considered at the elaboration stage of the development plan after thoroughly examining the above mentioned studies:

- Energy sources shortage and the existence of only one 330 kV OHL „MGRES - Artiz” lead to difficulties in the power supply of the customers from Odessa region of Ukraine, especially when local OHLs are being repaired. A new 330 kV OHL ,,Novoodesk - Artiz” with the total length of 104 km is designed to ensure the continuity of customers power supply [3, page. 17]. The transmission line is deemed to be built during the years 2016-2019, with capital investment of 1,63 billion HRU.
- The growth of electricity consumption in Odessa region, the overloading of electric network’s elements in the vicinity of the boundary between Republic of Moldova’s and Ukraine electric power systems, as well as the instable functioning of MGRES, lead to the construction of a powerful transformer substation 750/330 kV „Primorsk”, by interconnecting all the 330 kV and 750 kV networks from the region as: 750 kV OHL „Южно-Украинская АЭС – Исакча”, 330 kV OHLs „Котовская – MGRES”, „Усатово – MGRES”, „Аджалык – Усатово № 2”. The construction of „Приморская – Арциз” OHL is proposed as well on the basis of existing 330 kV OHL “MGRES – Artiz”, that consequently will be located on the territory of Ukraine *[3, pag.17*]. The construction of the electrical transformer substation 750/330 kV „Primorsk” (AT 750 kV – 2x(3x333)MVA; 750 kV OHL – 150 km, 330 kV OHL– 130 km) is envisaged for the period between 2016-2021. The overall cost of this substations will amount to 6,5 billion HRU. Furthermore, the 750 kV OHL „CHEA Dnestrovsk - Primorsk” shall be commissioned to the end of 2024 (3,2 billion HRU, 320 km).
- The carrying capacity of all electrical transmission lines that interconnect the electric power systems of Ukraine and Republic of Moldova amounts to 700 MW due to some technical constraints. The carrying capacity of mentioned links is significantly limited for the peak demand operating mode, and is equal to zero in case of maintenance works on local portion of 330 kV OHL – to 0 MW [3,page.34].

- The asynchronous interconnection of electric power systems of Romania and Republic of Moldova by back-to-back conversion stations is foreseen to increase the interchange capacity to the West of national power grid. The following steps are planned to enhance the electric transmission network, that will increase the interchange capacity provided by the 400 kV OHL „Isaccea (RO) – Vulcăneşti (MD)” and four 110 kV OHLs: The construction of 400 kV OHL „Suceava (RO) – Bălţi (MD)”, that depends on the construction of 400 kV OHL „Suceava – Gădălin”, being included in the development plan of electric transmission network of Romania [2, pag.16, page.156]. Transelectrica SA planned to increase the interconnection capacity with Republic of Moldova in 2018. The construction of 400 kV OHL „Suceava - Bălţi” is planned for the period 2017-2022, in a year after the construction of 400 kV OHL „Gădălin-Suceava” [2, page.160].
- Other projects regarding the interchange capacity enhancement with Republic of Moldova will be carried out as well to the end of finalization of the electric transmission network development plan of Romania. Those projects relate to the construction of the third 400 kV OHL in Iaşi – Ungheni area and the reinforcement of internal electrical line to the existing electric transmission network. The final solution shall be coordinated with the TSO of Republic of Moldova [2, pag.16].
- Two power units functioning at MGRES, which are connected remotely to the electric power system of Romania, are considered as a weak part from electrical transient’s point of view. Thus, the missing of teleprotection system on 400 kV OHL„Tulcea Vest – Isaccea” and the unavailability of teleprotection on double circuit 400 kV OHL „Isaccea – Smardan” would limit the MGRES’s power units loading to 130-150MW/per unit. It was reconnected to realize this scheme after all 400 kV OHL from that area would be equipped with teleprotection systems.
- The increasing of the electrical energy import in the vicinity of Republic of Moldova border was one of the main reasons why the absolute value of the electrical energy losses decreased as well as being correlated to the electrical energy that entered the loop of the electric transmission network of Romania [2, pag.60].
- The primary action plan regarding the preparing of the electric power system of Ukraine to be interconnected to ENTSO-E was developed. The actions shall have been taken during 2016-2017 with the total costs of 2,8 billion HRU [3, pag.44, annex 8]. It has to be mentioned that the first action of the plan is related to fulfill the obligations by Ukraine under the project ,,The study on the capability of synchronous interconnection of the electric power system of Republic of Moldova and Ukraine to the electric power network of ENTSO-E”.

It is to underline that both Romania and Ukraine intend to install renewable energy systems in the national electric power network due to its obligations towards European institutions.

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LIST OF ABREVIATIONS

ANRE	National Agency of Energy Reglementations
ATR	Technical conditions for conection
CEE	Wind power plant
CEF	Solar power plant
CNTEE	National Company of electrical energy transmission
CPT	Technological self-consumption
DPRA	Relay protecion and automation device
EMS	Energy Management System
ENTSO-E	European Network of Transmission System Operators for Electricity
EU (UE)	European Union
GMV	Minimum summer sag
IPS/UPS	Unified power system
LE	Electrical line
LEA	OHL
MD, RM	Republic of Moldova
OMEPA	Operator of counted electrical energy that entered the wholesale market
OST	Transmission system operator
OTS	Transmission and system operator
RMB	Medium summer operating regime
RD	Dimensioning operating regime
RET	Electric transmission network
RMI	Winter peak demand regime
RMV	Summer peak demand regime
RO	Romania
RTU	Remote terminal unit
SAMEE	Electrical energy monitoring system
SCADA	Supervisory Control and Data Acquisition
SE	Electrical substation
SEE	Electric power system
SEN	National electric power system
SESTMEE	The maintenance service of technical systems of electrical energy metering
SM	Metrological system
SOD	Operative dispatching service
UA	Ukraine
VPN	Virtual private network

1. GENERAL ASPECTS

1.1. Plan statement

The transmission system operator SE „Moldelectrica” intends to maintain the electrical energy transmission quality and the operational reliability of RET according to current regulations and the commitment towards neighboring countries at European level, by planning the development of electric transmission network. The TSO will refresh the plan of electric transmission network twice a year for the next ten years, in case of necessity. The mentioned development plan has to be approved by ANRE.

S.E. „Moldelectrica” develops, modernizes and retechnologises the RET under economic conditions to enforce its adequacy resulted from national electric power system evolution:

- The evolution of electrical energy consumption;
- The connection of new generating units to the public electric grid;
- The evolution of electrical energy interchange between national electric power network and those of neighboring countries;
- Technical and commercial obsolescence that belong to RET;
- The decommissioning of some generating units of power plants;
- Dramatic change of power flows in the key elements of RET;
- Dramatic change of electrical energy losses in the electric transmission network.

Solution will be found by a cost/benefit analysis based on the assessment of some special technical and economical parameters in case of the necessity to develop the RET. The solutions satisfying more scenarios will be chosen due to the uncertainty related to the electric power system and economic frame uncertainty. The mitigation of the impact on the environment according to modern accessible technical performances and current regulations are deemed for every project.

It shall be mentioned that the directions of performed services efficiency are followed:

- Maintenance works performance to ensure the TSO operational reliability;
- The implementation of innovative technologies and modern practices;
- The promotion of SE ,,Moldelectrica’s” electrical equipment telecontrol and intelligent metering of electrical energy to provide an adequate infrastructure pursuant the development level of electrical energy market;
- The promotion of solutions to enchance electrical energy losses decrease in the RET;
- The decrease of congestions in the RET.

Hence, it shall be mentioned that RET development plan is compliant with all the requirements and priority tasks specified in the National power energy strategy and policy. These requirements served as milestones for the definition of the priority directions and the evolution forecasting tendencies in the power energy sector.

One of the European Union’s priorities is to reduce the carbon emissions and to encourage the electrical energy consumption from renewable sources. The legal package regarding climatic change and the renewable energy dated 23 January 2008, to cover 20% of electrical energy consumption by renewable energy sources until 2020.

1.2. Scope and objectives

The TSO SE ,,Moldelectrica” must be capable to satisfy the reasonable request of performing electrical energy transmission services, developing and executing prospective plans regarding the development and emerging of electric transmission network according to electricity production and consumption forecasting, to plan the RET development and to prepare a development plan for the next ten years, based on the commitments and the statements of Electrical Energy Law nr. 107 dated 27.05.2016 [1] and the conditions stipulated in the license nr. AA 064574 [4] regarding electrical energy transmission and system services, for approval to the grid owner and ANRE. Once per two years the TSO will examine the necessity of development plan amendment and will submit for approval the amended development plan if necessary or at ANRE request.

The planning of RET development defines the objectives:

- National electric power system reliable operation and high level of transmission service compliant with the standards of RET’s technical regulations [5];
- RET development shall be properly scaled for the transmission of forecasted production, consumption, import, export and the transit of the electrical energy;
- The provision of electrical energy transmission infrastructure that is necessary for a proper functioning of electricity market;
- Access provision for the public electric network under current regulations;
- Capital investment mitigation at the stage of identifying the solutions of RET development.

1.3. Regulatory framework

1.3.1. Primary legal framework

The main regulatory documents that are deemed to regulate the energy sector in the Republic of Moldova and have the major impact on the RET development are:

- Electrical energy law [6];
- Law regarding the transparency of taking decisions law [7];
- Renewable energy sources law [8];
- Energy sector law [9];
- Law regarding the promotion of the electrical energy use, produced from renewable energy sources [10];
- Metrology law [61];
- Decision on the implementation of some clauses of law Nr. 107 regarding the electrical energy and the law Nr.8 regarding the natural gas [11];
- Directive of EU Parliament and of the Council on the promotion of the use of energy from renewable sources [12];
- Directive of EU Parliament and of EU Council on the common regulations for the internal market of electrical energy [13];
- Regulations of the European Parliament and of the Council on conditions for access to the network for cross-border exchanges in electricity [14];
- Directive of the EU Parliament and of the Council on measure to ensure the safety of electricity and infrastructure investment [15];
- Government Decision on the roadmap for the electricity sector in Republic of Moldova [16].

1.3.2. Secondary legal framework

The secondary legislation covers those regulatory tools that are mandatory for the market participants to work coordinately and synchronously:

- Electrical energy market rules [17];
- Electric transmission network technical norms [5];
- Electric distribution network technical norms [18];
- The methodology of establishment, approval and implementation of the tariff on electrical energy transmission service [19];
- The regulatory on the provenance guarantee regarding the electrical energy produced from renewable energy sources [20];
- The methodology of establishment, approval and the implementation of the tariff on the electrical energy produced from renewable energy sources and biofuels [21];
- The regulatory on the parallel functioning of the electric power system and the power plants deemed to produce electrical energy for internal needs [22];
- Guidance on electrical energy losses calculation in the electric transmission network [23];
- The regulatory on the quality of electrical energy transmission and distribution services [24];
- The regulatory on the electrical energy metering for commercial use [62].

2. CURRENT STATE ANALYSIS

2.1. Electricity transmission network structre

2.1.1. General data

The Republic of Moldova is geographically located between the borders of EU power system, ENTSO-E (the power system of Romania is to the West) and the IPS/UPS system (the power system of Ukraine is to the East), depending significantly on it (Figure 2.1).

Figure 2.1 RET of Republic of Moldova

SE „Moldelectrica” is providing electrical energy transmission services by RET that consists of transformer substations and High Voltage and Ultra-High Voltage transmission lines. The electric RET is the electric grid of national and strategic interest with phase-to-phase voltage equal or greater than 35 kV.

The amount of electrical equipment kept in operation at TSO SE „Moldelectrica” consists of:

- **183** electrical transformer substations (SS) 10 - 400 kV (Figure 2.2),
- **4704,41** km of electrical overhead lines (OHL) 35 – 400 kV (Figure 2.10),
- Power transformers and autotransformers with total power of **5071,8** MVA, as follows:
  - 2×250 MVA
  - 7×200 MVA
  - 1×125 MVA
  - 2×63 MVA
  - 4×55 MVA
  - 13×25 MVA
  - 60×16 MVA
  - 44×10 MVA
  - 119×6,3 MVA
  - 1×5,6 MVA
  - 31×4 MVA
  - 5×3,2 MVA
  - 31×2,5 MVA
  - 1×1,6 MVA
  - 1×1 MVA
  - 1×0,4 MVA

SE „Moldelectrica” deploys a rigorous maintenance program to maintain the technical condition of its electrical installations to comply with the requirements of service quality enforced by Technical regulations of electric transmission networks [5], being related to the license of electric power transmission and the provision of system services.

The main goal of the maintenance program is the enhancement of the RET operational reliability to avoid situations that may lead to undesirable accidents for the transmission grid, people or environment.

2.1.2. Current technical condition of primary equipment

It was stated above that 183 of electrical substations (Figure 2.2) with primary phase-to-phase voltage of 10-400 kV, and total installed power of 5071,8 MVA belong to the TSO.

All the SS kept in operation by TSO were built and commissioned in the soviet times as little investment was made for system development by construction of new transformer substations and overhead power lines since Republic of Moldova Independence proclamation.

SS operation time show a high level of equipment obsolescence as the operation period of nearly 80% of the equipment is more than 30 years (Figure 2.2 and Figure 2.3).

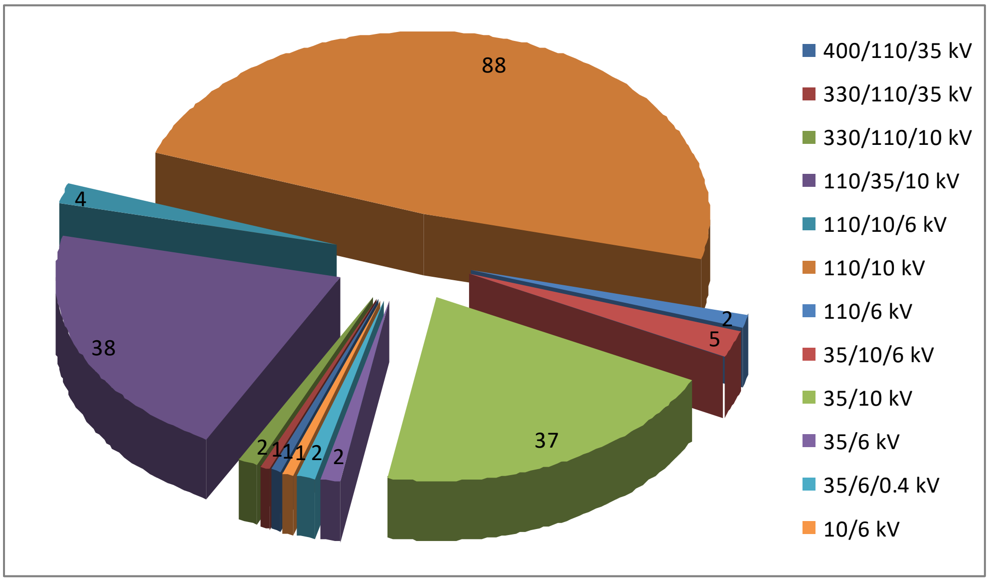

Figure 2.2 Number of SS that belong to the TSO

During last 25 years no big capital investment was made in electrical substations overall reconstruction, except for SS Bălţi 330 kV (330kV and 110kV switchyard); SS Străseni 330kV (330kV switchyard); SS Chişinău 330kV (330kV switchyard); SS Vulcăneşti 400 kV (two bays out of five in 400kV switchyard) and totally SS Anenii Noi 110/35/10 kV (without exchanging the power transformers).

The wide variety of electrical substations of different nominal voltages is bound with a wide variety of electrical equipment that belongs to them.

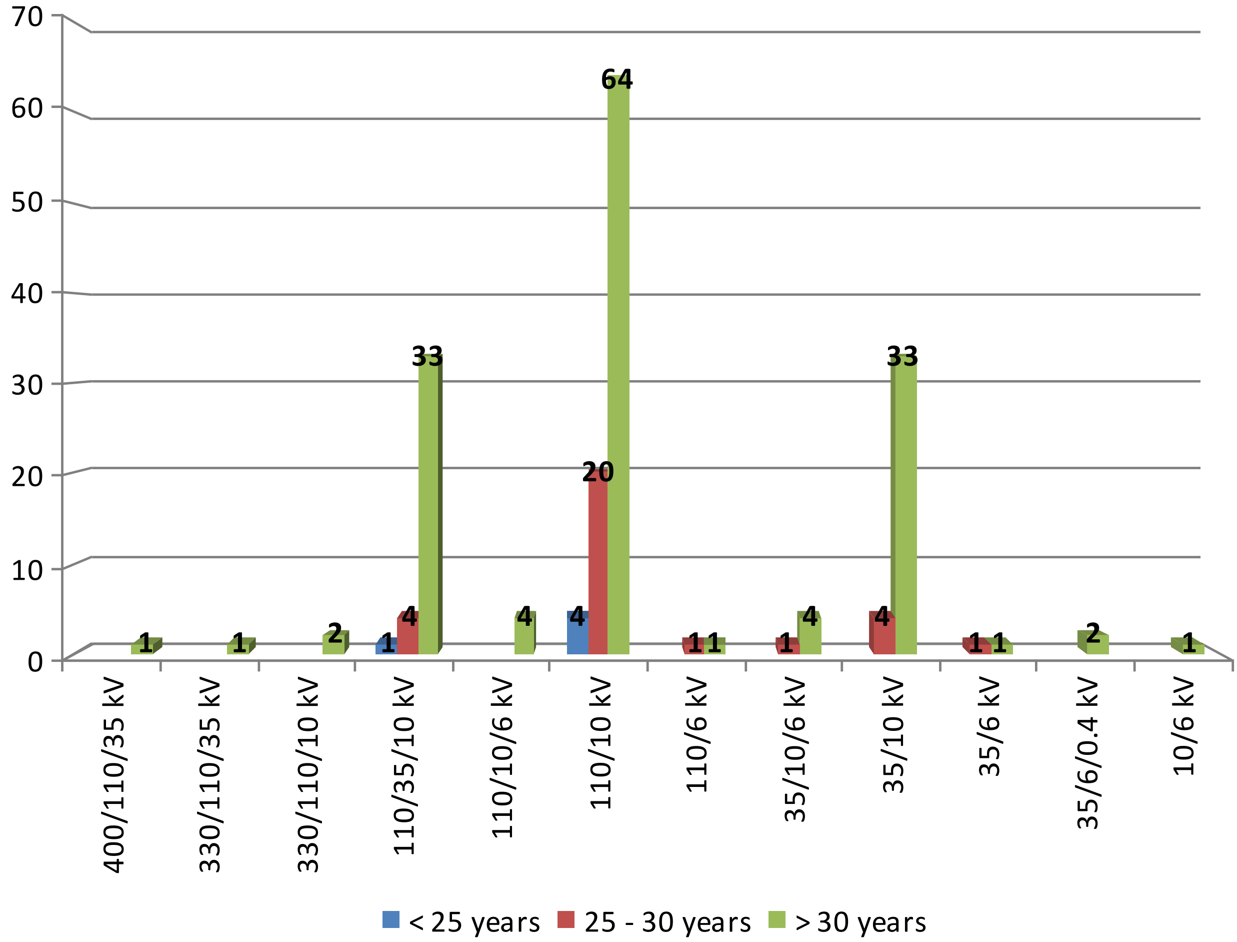

Figure 2.3 The operation period of TSO's electrical substations

Important to the electric power system technical characteristics are the technical state and the operating period of the power transformers.

Three hundred twenty four power transformers, boosters and shunt reactors with nominal voltages of 35-400 kV are in operation at SE „Moldelectrica". The information about the nominal power and the operating period of the power transformers installed at the TSO's electrical substations is depicted in the figure 2.4.

Nearly 40% of the power transformers with the operating period of more than 30 years are exposed to a high risk but still in function being continuously monitored, due to a maintenance program that provides periodical checking, current and overall maintenance.

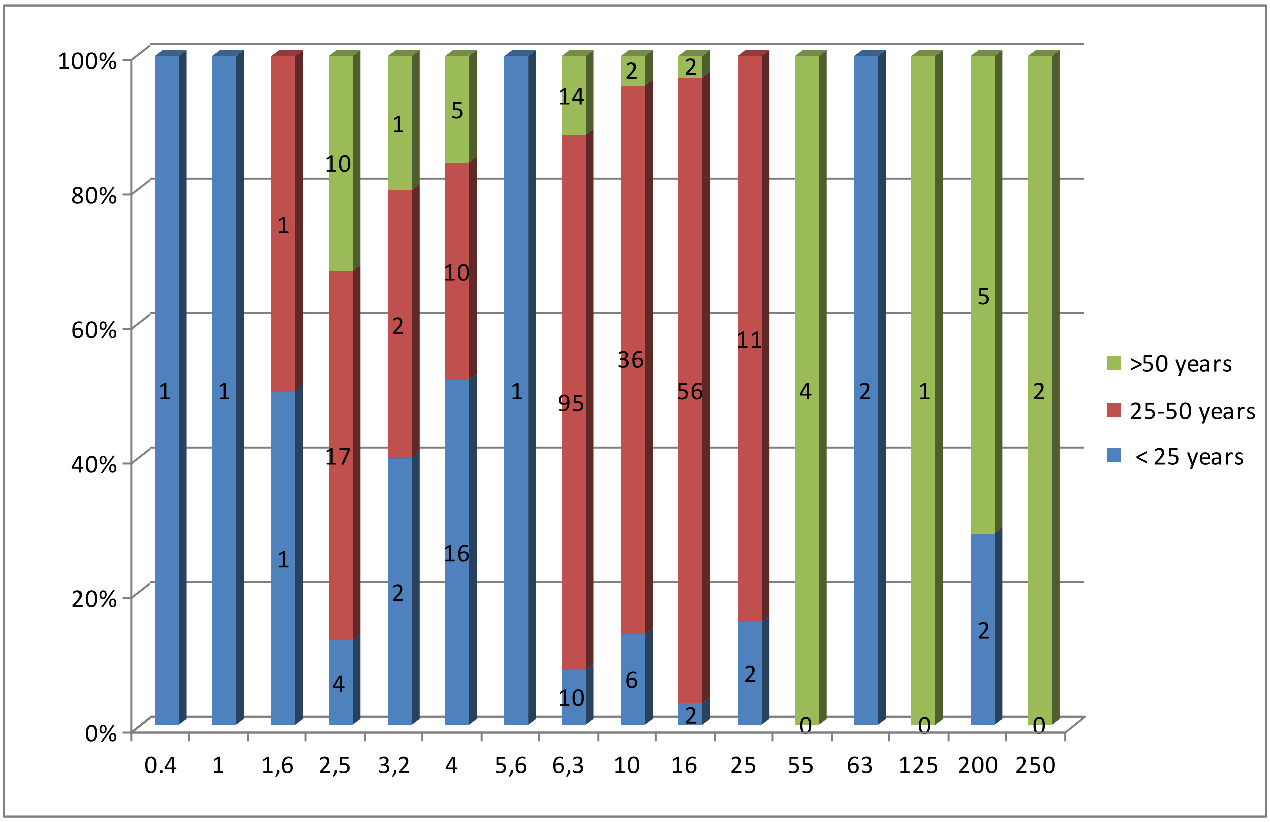

Figure 2.4 Operating period of TSO's power transformers.

Almost 75% of 2717 circuit breakers of 10-500 kV, being in operation at SE „Moldelectrica", are of oil type. These circuit breakers are not produced any more and it is increasingly harder to find spare parts for them.

Air type circuit breakers of 110 and 500 kV are also currently in operation. A good maintenance shall be provided for their compressor stations.

Also, just 1% of medium voltage switchgear bays out of more than 3000 operated at SE "Moldelectrica" are of latest generation with operation period less than 25 years.

This situation is caused by the policies of 10 kV switchgear development and refurbishment that envisage the installation of vacuum circuit breakers instead of oil type and the secondary circuits related to them in the existing precast bays.

Problems caused by bad sealing of the bays, and flaws of 6-10 kV switchgear bushings occur more often because the existing bays date from soviet times.

SE „Moldelectrica" assures the necessary reliability level for a proper functioning of the RET due to a coherent policy of electrical equipment maintenance by performing periodical checkings, tests and continuous monitoring of main parameters evolution despite a long operation period of the equipment.

Also it is outlined that the situation becomes worse by every year, what is reflected by a big number of installations that are in poor condition and need to be refurbished, overhauled or replaced now (Figures 2.5 – 2.9).

This situation is caused by limited budget funds to be used for the capital investment, being gained from the transmission and electric power system dispatching tariffs.

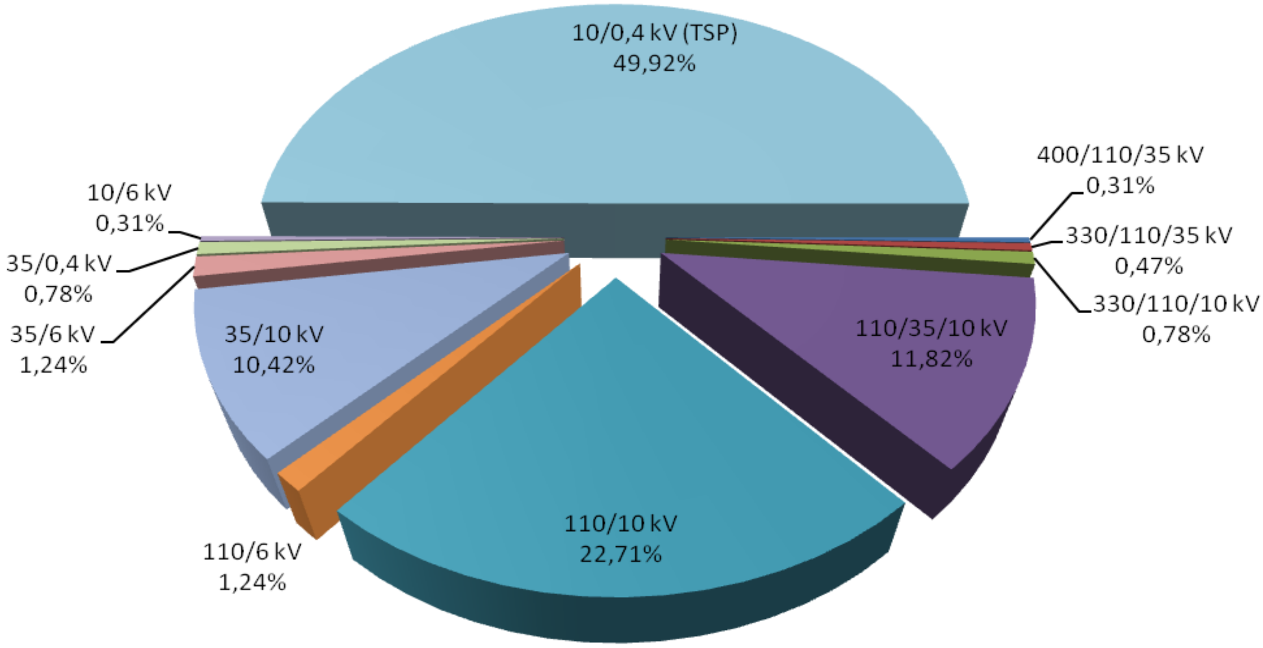

Figure 2.5 The rate of the power transformers from TSO's electrical substations

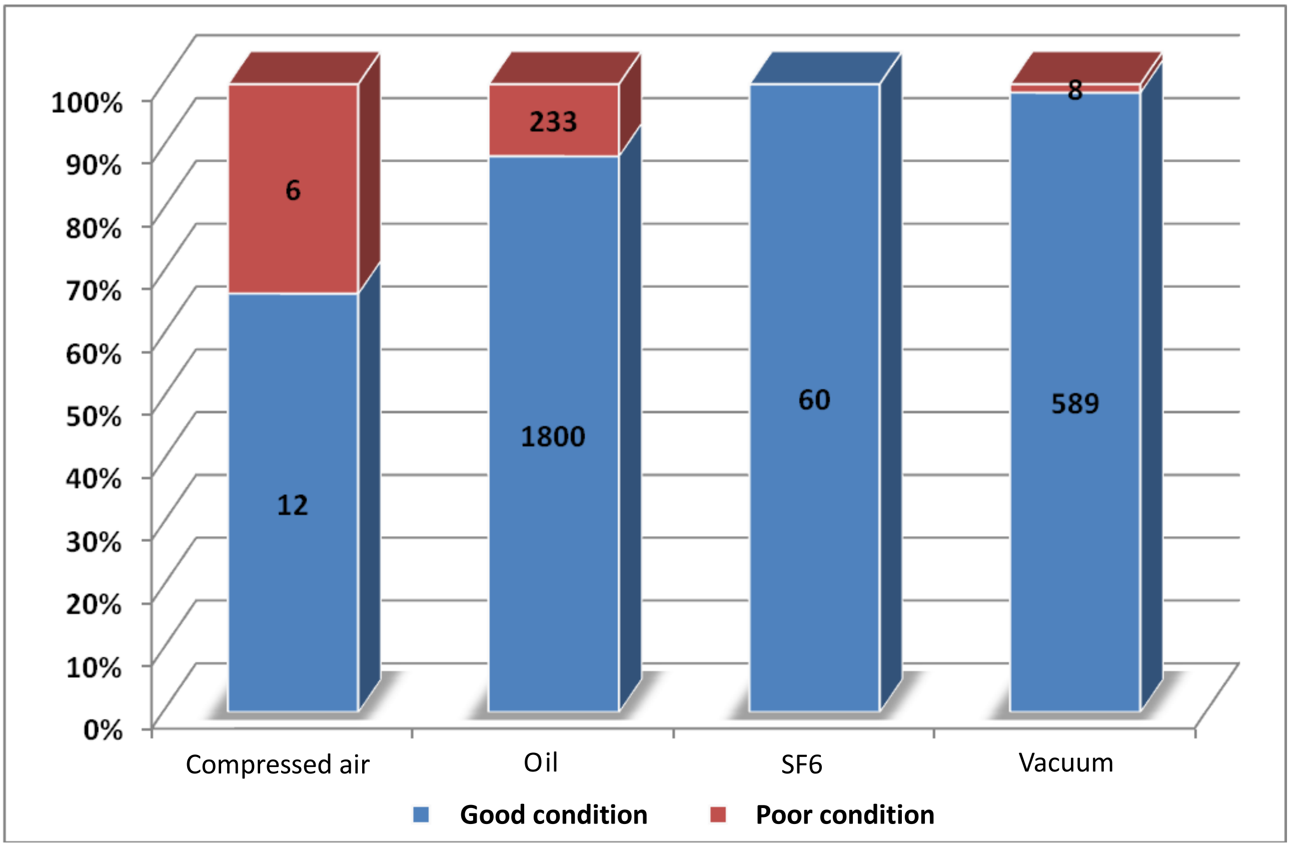

Figure 2.6 TSO's circuit breakers technical state

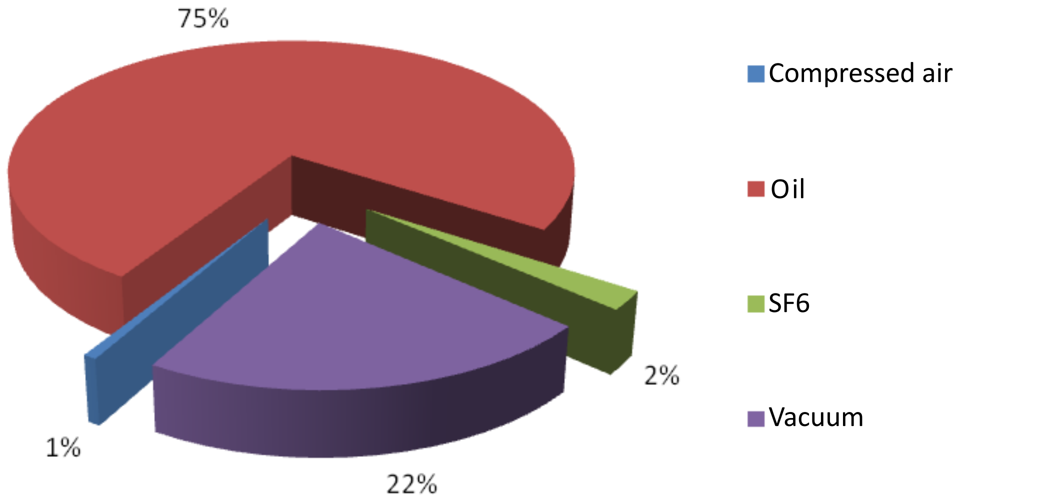

Figure 2.7 The rate of the 10-400 kV TSO's circuit breakers

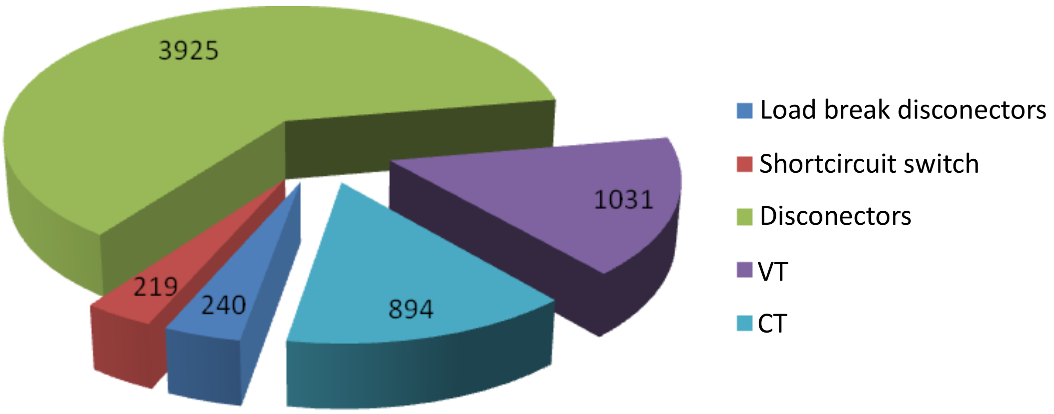

Figure 2.8 The rate of TSO's electrical equipment

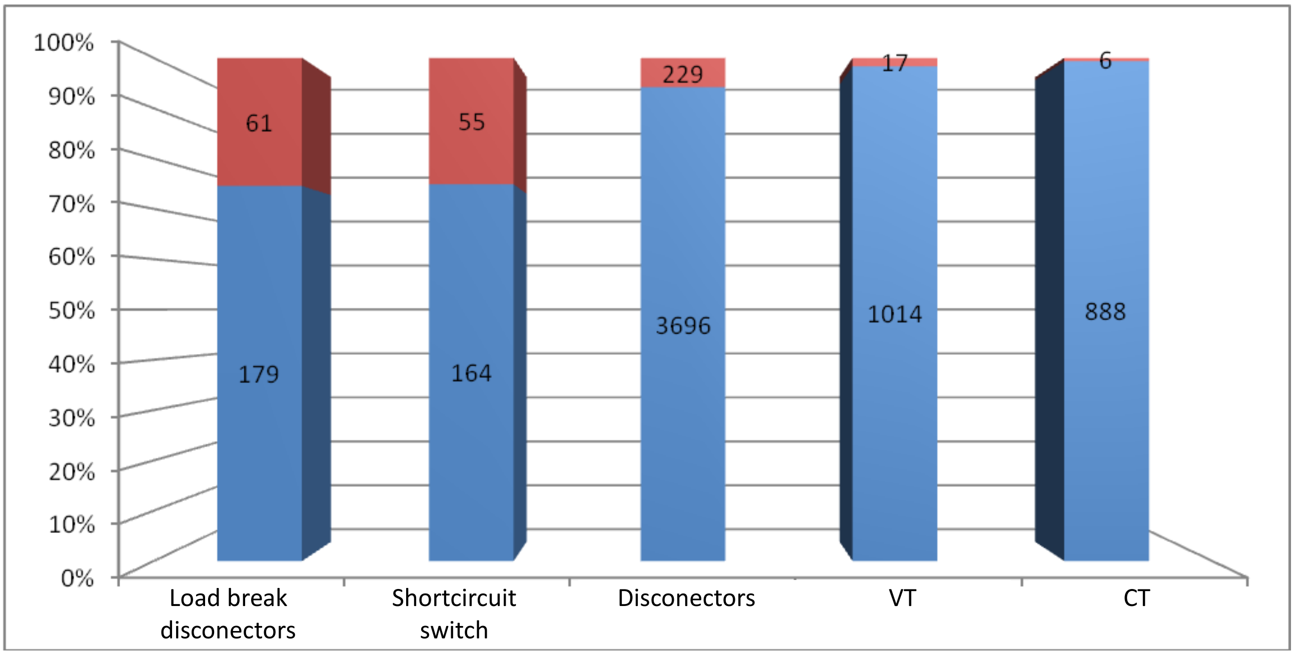

Figure 2.9 TSO's electrical equipment technical state

2.1.3. Electrical lines current technical condition

Most of electrical installations’ faults result on OHLs due to vast geographic areas and operation conditions. The faults may be caused by insulation aging or some external reasons (atmospherical overvoltage, insulators break, wire break, swinging cross and their contact with the ground, etc.).

The general data of TSO’s OHLs is presented in the Figure 2.10 (**4704,41** km of 35 – 400 kV OHLs).

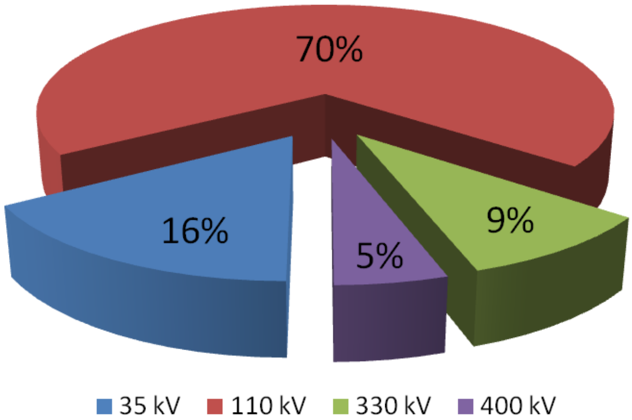

Figure 2.10 The rate of TSO’s OHLs at different nominal voltages

The rate of the OHLs with concrete pylons is depicted in the Figure 2.11 as their number is much higher than of OHLs with metal lattice towers.

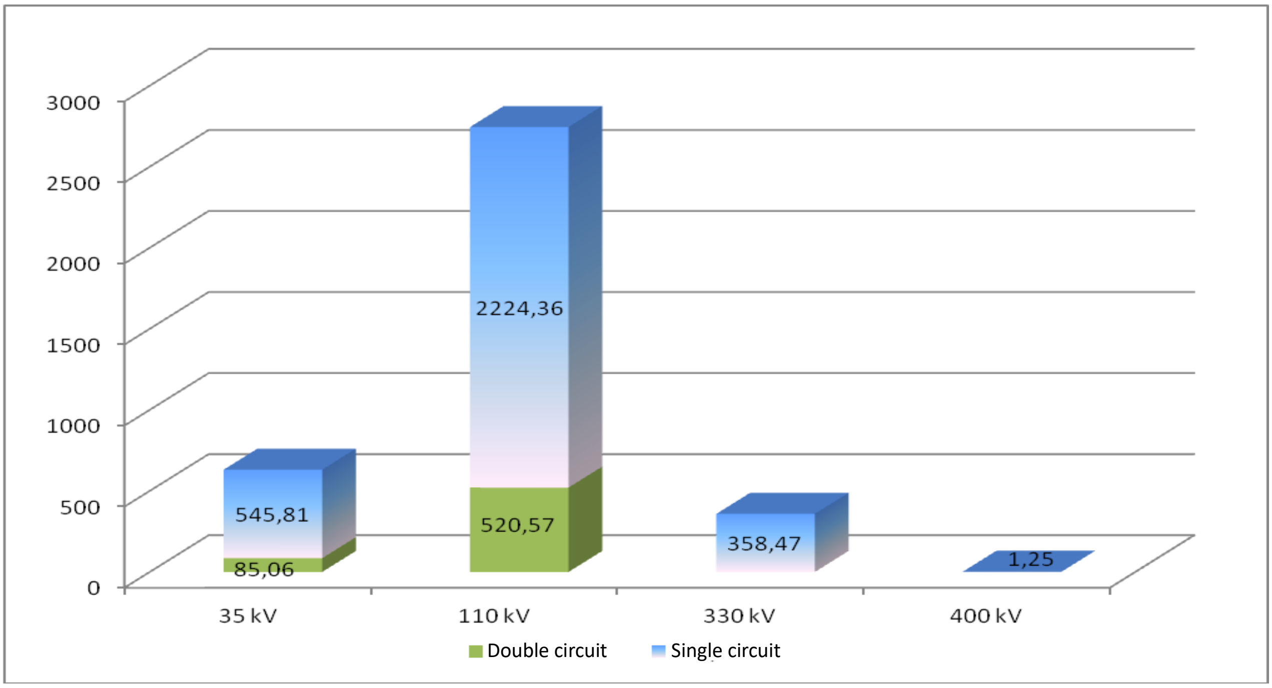

Figure 2.11 The rate of OHLs with concrete pylons

The data on OHLs operating periods is depicted in the Figure 2.12.

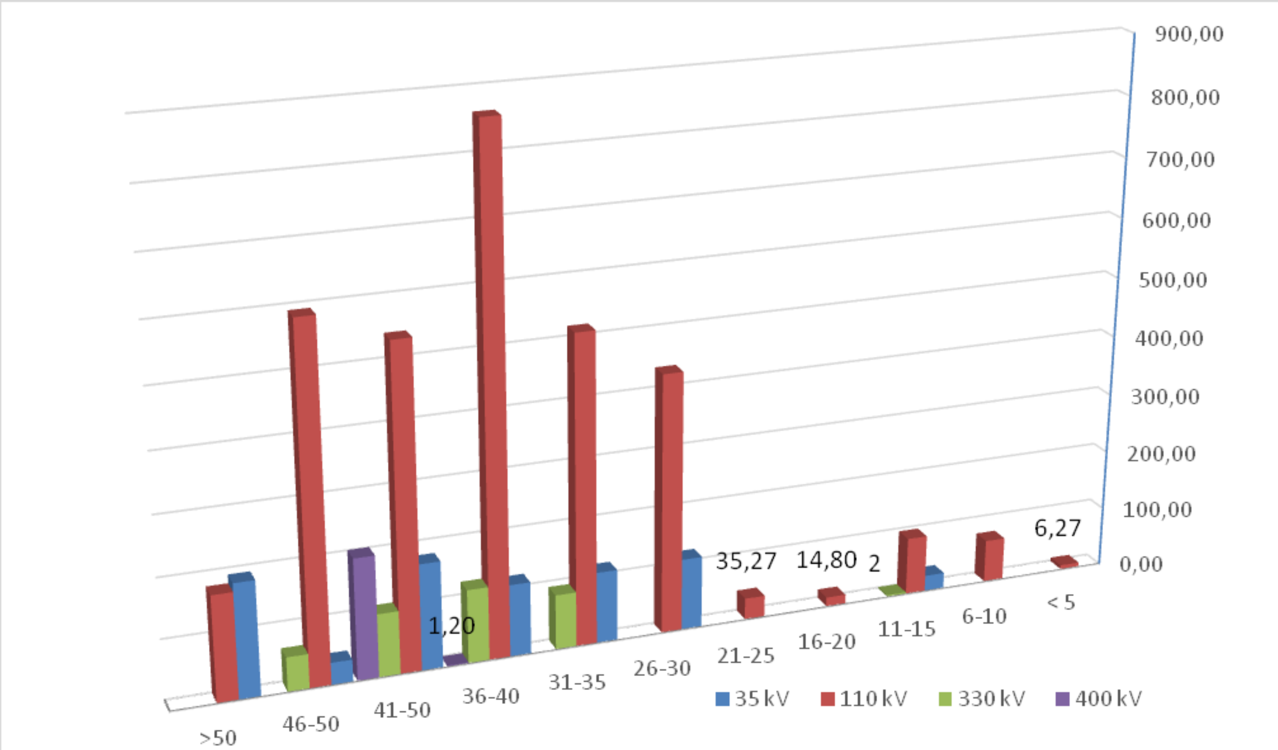

Figure 2.12 OHLs operating period

The operating period of 67,5% of the OHLs that belong to SE "Molelectrica" is more than 40 years as depicted in the Figure 2.12. The necessity to rehabilitate the existing OHLs and/or to build new ones is of importance to the TSO. Primarily the OHLs which being tripped will mostly influence the electric power system's operation reliability will be included in the Development Plan of the Electric Transmission Network for the period 2018-2027 due to limited budget funds.

2.1.4. Technical condition of power system protection, automation and telecontrol equipment

Only the correct functioning of protection, automation and telecontrol systems of TSO's RET can lead to the continuous power supply of the consumers.

The general information about the protection and automation systems is depicted in the Figures 2.13 and 2.14. The operating periods of protection and automation systems are presented in the Figure 2.15.

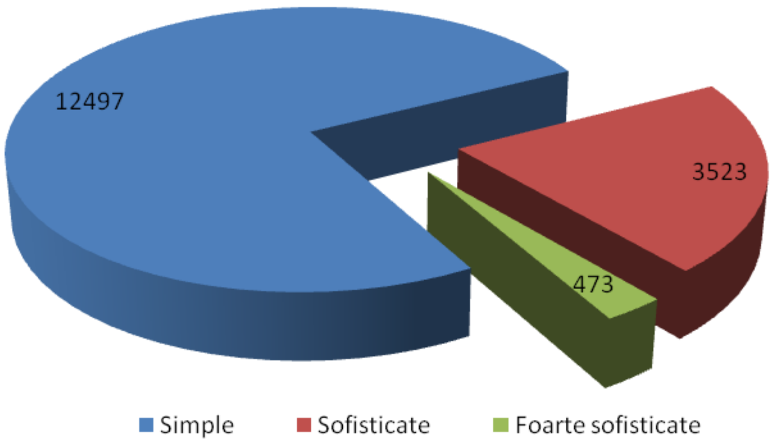

Figure 2.13 The information about protection and automation systems

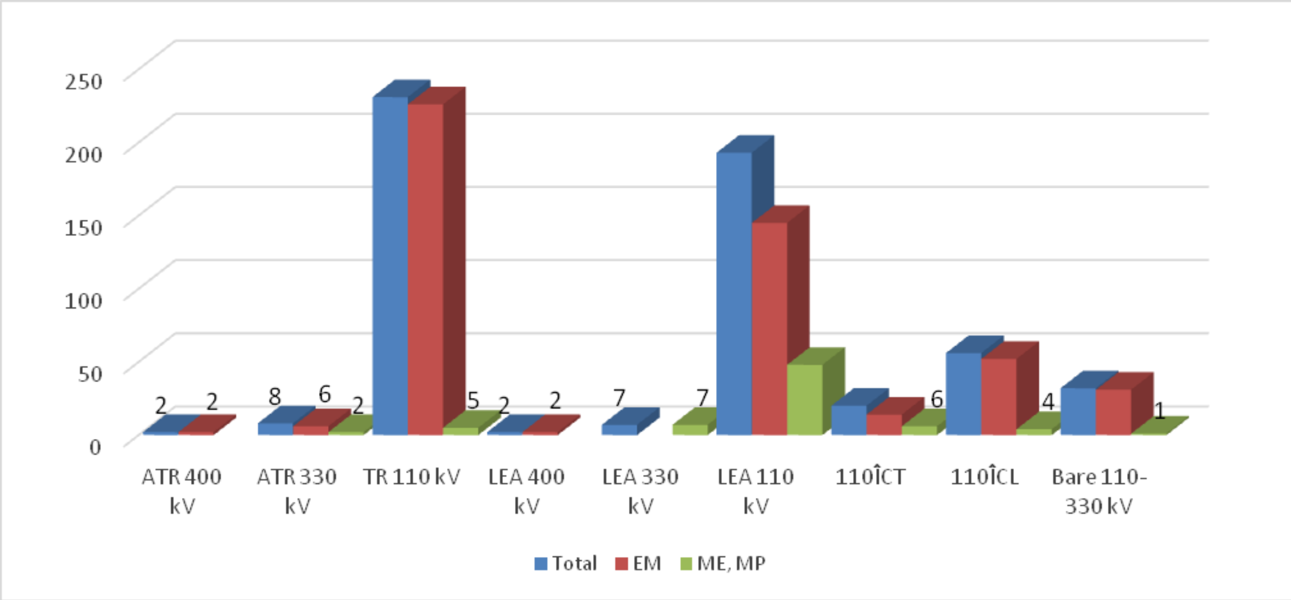

Figure 2.14 The total number of protection and automation systems’ equipment

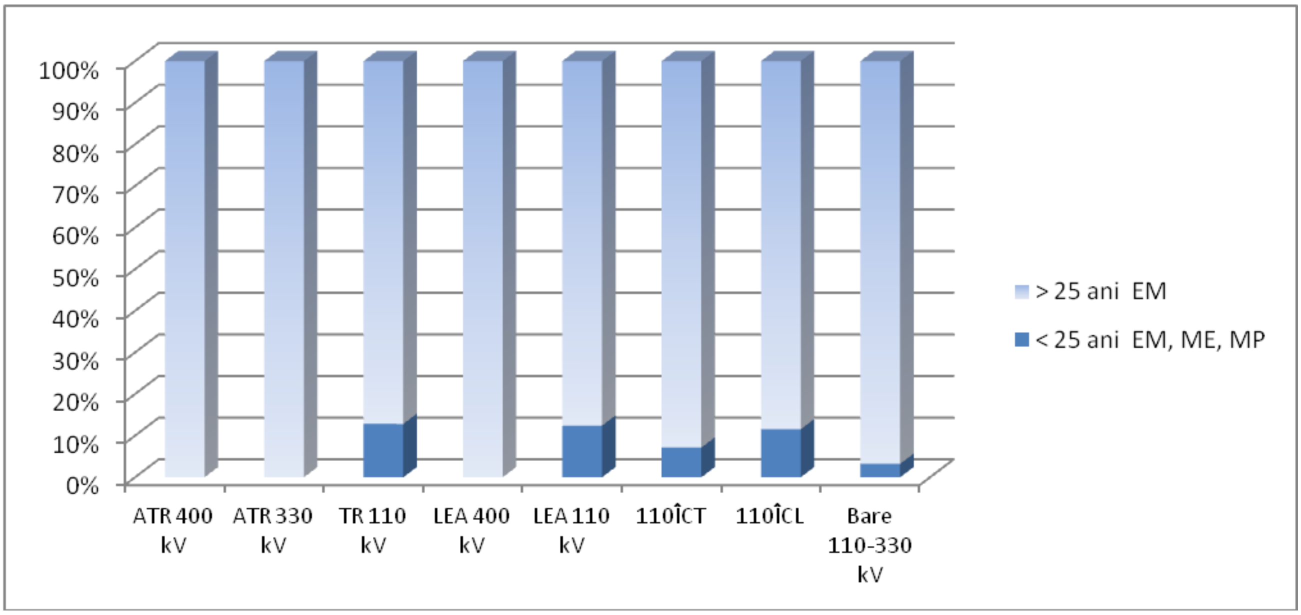

Figure 2.15 The operating periods of protection and automation systems

The information about TSO’s electric transmission network telecontrol equipment and its operating periods is depicted in the Figure 2.16.

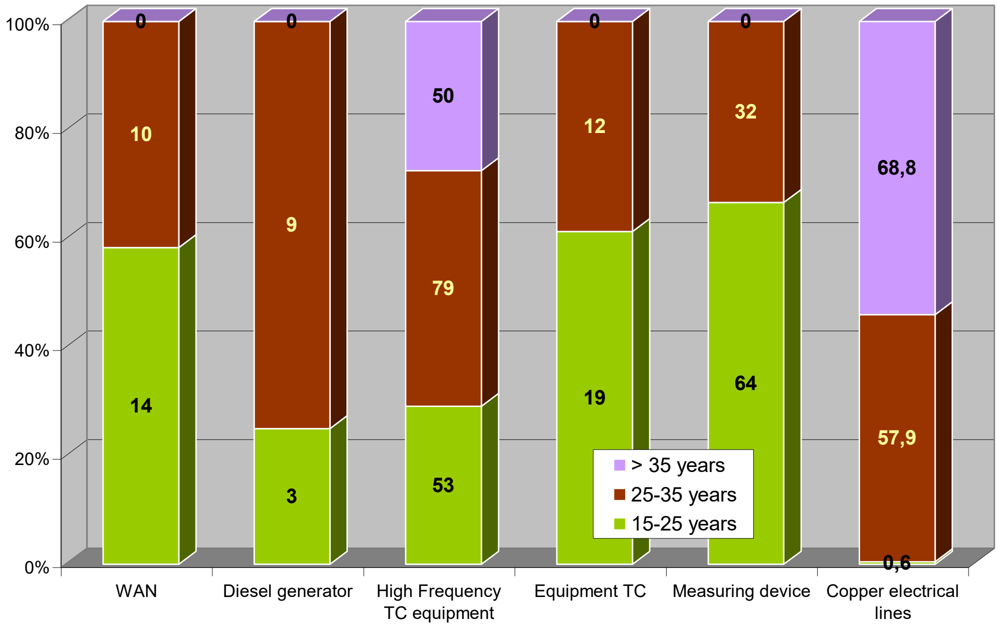

Figure 2.16 The information about telecontrol equipment of TSO’s electric transmission network

2.2. Electricity consumption

The evolution of annual net active electrical energy consumption and the annual medium power in the period 2001-2016 is depicted in the Figure 2.17. The annual medium power varied form 560 MW (year 2002) to 664 MW (year 2008) during this period. The net electricity consumption raised annually by 0,57-13,47% for the region from the right bank of Nistru river except the years 2009 and 2016. The first decrease of net consumption in 2009 amounted to 0,6% in comparison with 2008, and - to 0,35% in 2016 in respect to 2015, due to the economic and financial crisis.

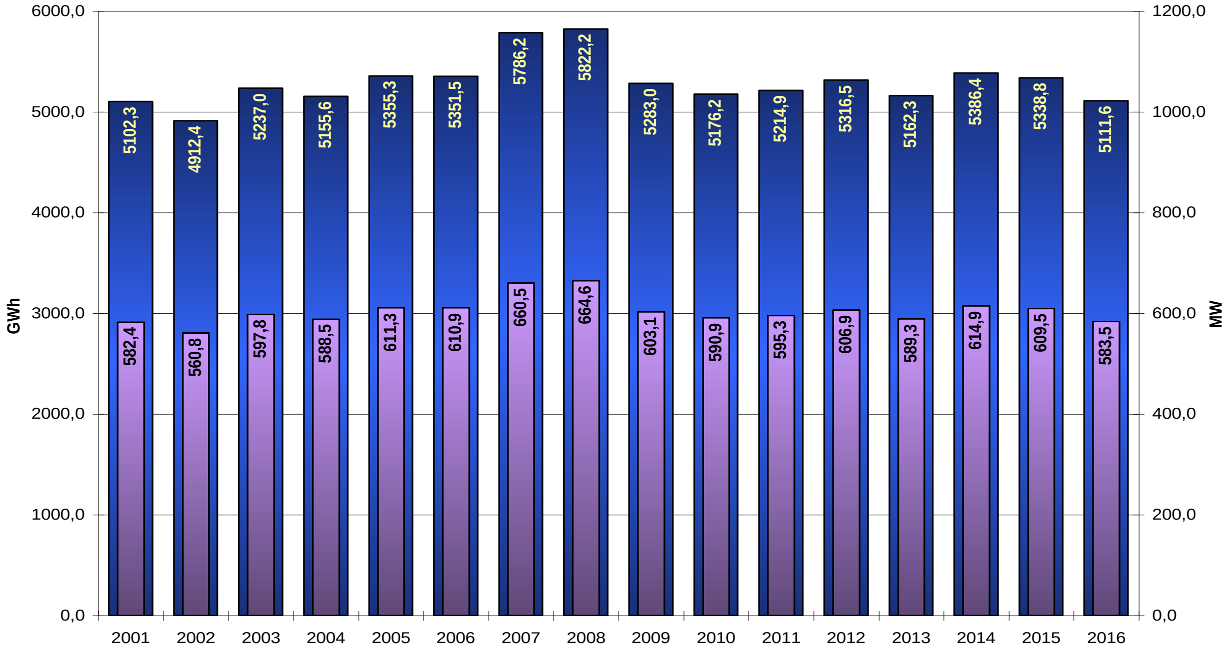

Figure 2.17 The evolution of electrical energy consumption in the period 2006-2017

The maximal/minimal active consumed power amounted to 991/514 MW in winter day (21.12.2016) and - to 674/361 MW (15.06.2016) in summer day accordingly based on the analysis of daily load curves for the typical days of the year 2016.

The duration load curve's smoothing coefficient for the typical winter/summer day amounts to 0,519/0,536. Therefore, the load curve smoothing can be considered an important measure for reducing the electrical energy losses in RET. It is necessary to mention that smoothing coefficients reached similar values for last years.

2.3. Electricity production

Depending on the primary energy source used to produce the electricity in the national power system the following types of power plants are being in operation: thermal power plants (based on natural gas, coal or oil fuel), combined heat and power plants (based on natural gas or oil fuel), biomass power plants, hydroelectric power plants, wind and solar power plants (Table 2.1).

The main energy sources in Republic of Moldova are the thermal power plant CERSM and the combined heat and power plants with a total installed power of 2999 MW [26]. The rest of the electrical energy is produced by hydroelectric power plants and renewable energy sources. The evolution of local generation of electrical energy during the period 2001-2016 is depicted in the Figure 2.18.

Table 2.1 Electrical energy provision to RET in 2016

Energy source	Installed power, MW	Provided electrical energy, mil. kWh
CHP-1 Chişinău	66	33,311
CHP-2 Chişinău	240	607,322
CHP Nord Bălţi	24	54,631
Hydroelectric plant Costeşti	16	38,619
Other generation sources	87	16,371
Renewable energy sources	6,9	17,818
CERS Moldoveneasca	2520	4170,397
Hydroelectric plant Dubăsari	48	187,263

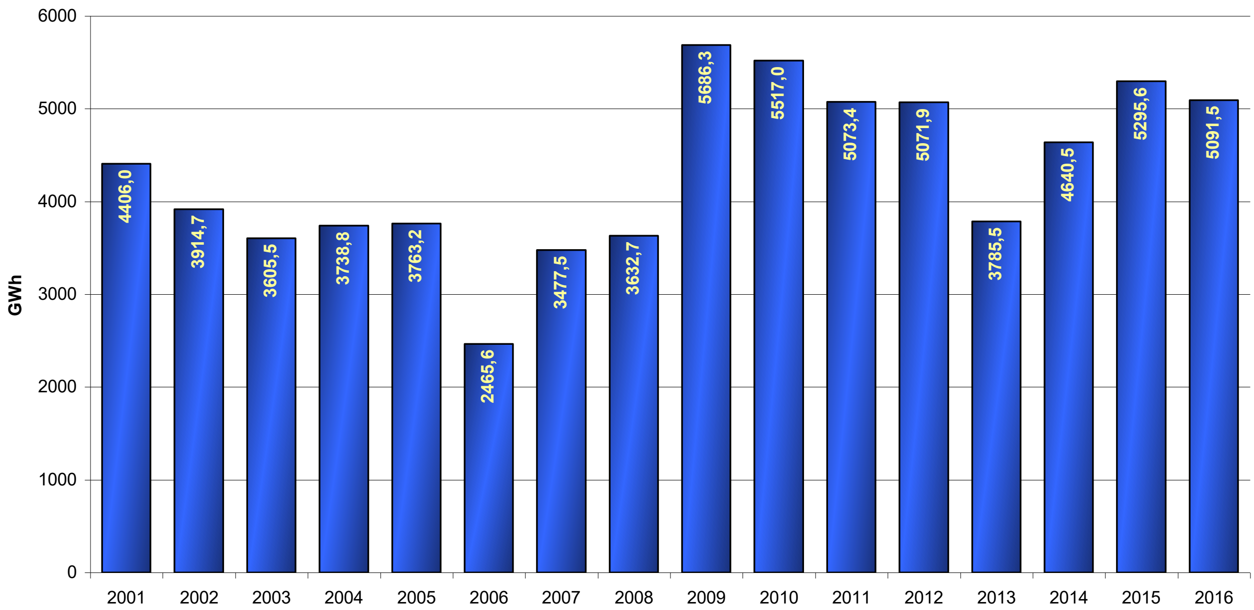

Figure 2.18 The evolution of local electrical energy generation in the period 2001-2016

The local electrical energy generation on the right bank of Nistru river has decreased by 1,38-11,6% in the mentioned period except the years 2005, 2010, 2014 and 2015, based on the presented data. The decrease of electrical energy generation is caused by the decrease of thermal energy consumption in the thermal district heat system, as the main local energy sources are combined heat and power plants.

The detailed information regarding the connection of renewable energy sources to RET, the conditions of submitting an application to get the technical approval of connecting [27], as the special technical requirements to be fulfilled by the renewable energy source [28] are presented on the web page of SE “Moldelectrica”.

The evolution of power plants installed capacities based on renewable energy sources [59] as well as the evolution of generated electrical energy from different types of renewables (solar energy, wind energy and biogas produced from biomass) during the period 2011-2016 is depicted in the Figure 2.19. In 2016 the electrical energy generation from renewable energy sources amounted to 17,818 mln kWh [59].

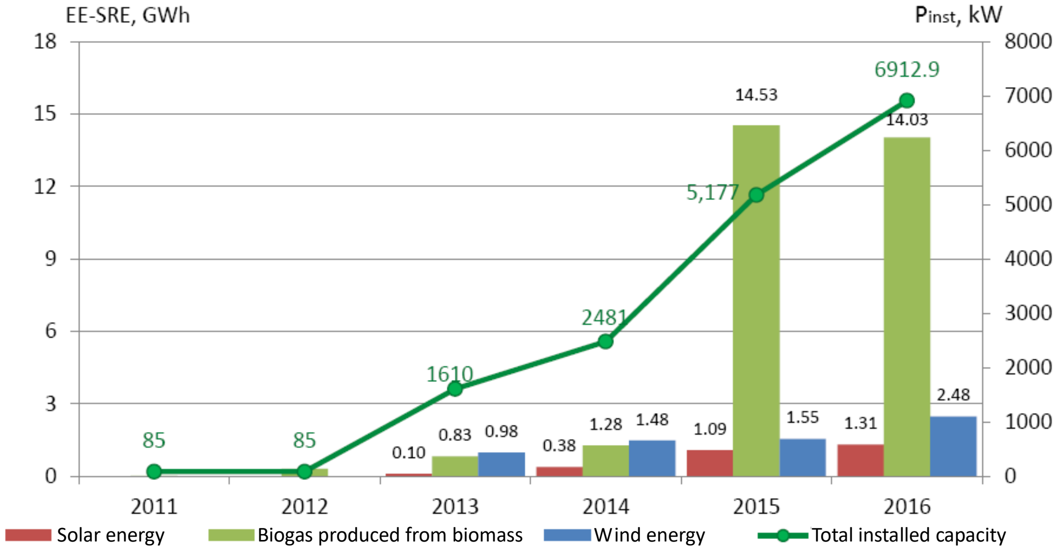

Figure 2.19 The evolution of generated electrical energy from different types of renewables and the evolution of total installed capacity

The structure of the generated electrical energy in 2016 year is depicted in the Figure 2.20. The total amount of the electrical energy imports and export from CERSM is greater than 80% according to the information presented in the chart.

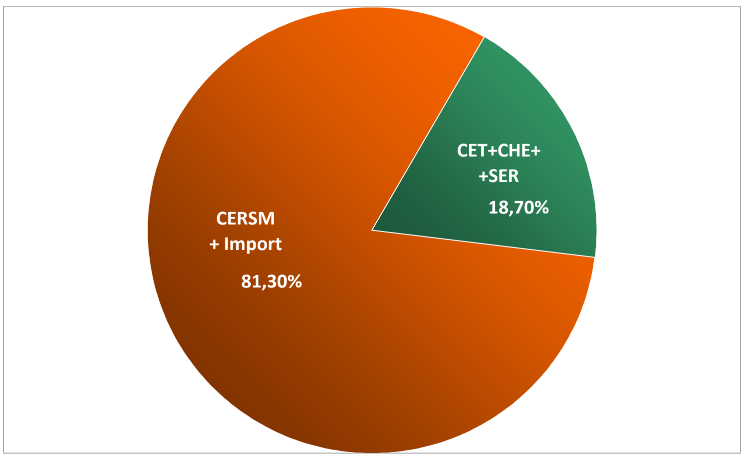

Figure 2.20 Electricity generation chart

Therefore, it was stipulated in the Energy Strategy 2030 that the installed capacity of electrical energy generation in the Republic of Moldova is the prerequisite to create a new generation platform that will stand for the economic enhancement and consumption balance within the energy community, what is possible by the real integration of Moldova's electricity market in the regional market [29].

2.4. Electric power systems interconnection

The interconnection of the electric power systems of Romania and Republic of Moldova is performed by 110 kV and 400 kV OHLs that are operated in island mode (Table 2.2).

Table 2.2 The OHLs of interconnection with the electric power system of Romania

Nominal voltage	OHL designation
400 kV	Vulcăneşti - Isaccea
110 kV	Costeşti - Stînca
110 kV	Ungheni - Ţuţora
110 kV	Cioara - Huşi
110 kV	Goteşti - Fălciu

At the same time the interconnection of the power systems of Ukraine and Republic of Moldova is very wide, being performed by numerous 110 kV and 330 kV electric lines that are operated synchronously (Table 2.3). The electric power system of Ukraine is synchronously functioning with the electric power systems of Russian Federation, Republic of Belarus, Republic of Moldova, except the islands „острова Бурштынской электростанции" (that comprise Бурштынская thermal power plant, Калужская CHP and Теребля-Рикская hydroelectric power plant), that are operated synchronously wit ENTSO-E. The electrical ties between these power systems are made by the electric networks 110-750 kV [*3, pag.9*].

The interstate ties include 7 330 kV OHLs and 11 110 kV OHLs with Ukraine, 4 110 kV OHLs and 1 400 kV OHL with Romania.

<u>The access to the interstate OHLs and the carrying capacity between MD-RO power systems.</u>

The electrical energy exchange between Romania and the Republic of Moldova is limited by the island operating mode because their electric power systems currently can't be operated synchronously. The decision on the access to the interstate OHLs between Romania and the Republic of Moldova is taken by CNTEE - Transelectrica S.A. The evolution of electricity export from the electric power system of Romania in the period 2001-2016 is depicted in the Figure 2.21.

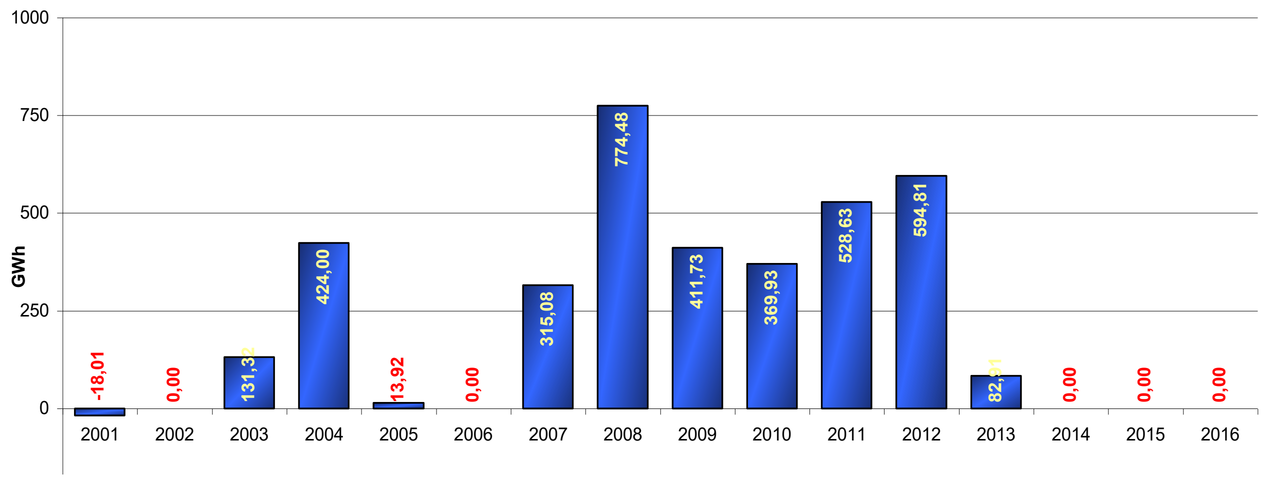

Figure 2.21 The evolution of electrical energy export form Romania in the period 2001-2016

The access to the interstate OHLs and the carrying capacity between MD-UA power systems.

The electrical energy exchange between Ukraine and the Republic of Moldova is determined by the “control section”, its maximal power being limited by the technical requirements of electric power system operational reliability. The control section includes: 4 330 kV OHLs, 3 internal OHLs of Ukraine’s national power system, 330 kV OHL Adjalîk - Usatovo 1, 330 kV OHL Adjalîk - Uasatovo 2 and the 330 kV OHL Ladîjenskaia CHP - Kotovsk; and a tie between Ukraine - Moldova, the330 kV OHL Hydroelectric power plant Dnestrovsk - Bălţi (Table 2.3).

The bulk power transmission could be ensured by the mentioned OHLs to the Republic of Moldova, Ukraine and region of Odessa or the import/export at the same time. Maximum power values are determined for the control section with regard to its carrying capacity, which depends significantly on the topology of 330 kV OHLs and the componence of those four electric power lines. The limited value also depends on the power generated at CERSM and at the hydroelectric power plant Dnestrovsk. Therefore, due to the separation of the import/export areas on the OHL at the interstate boundaries, the allowed carrying capacity of the electrical energy import from Ukraine to the electric power system of Republic of Moldova is the remanent value of control section’s transmission capacity, except for the region of Odessa.

Table 2.3 The OHLs of interconnection with the electric power system of Ukraine

Nominal voltage	OHL designation
South electric power system (Odessa)	
330 kV	CERS Moldovenească - Novoodeskaia
330 kV	CERS Moldovenească - Usatovo
330 kV	CERS Moldovenească - Podolskaia
330 kV	CERS Moldovenească - Arţiz
330 kV	Podolskaia - Rîbniţa 1
330 kV	Podolskaia - Rîbniţa 2
110 kV	CERS Moldovenească - Beleaevka
110 kV	CERS Moldovenească - Razdelinaia
110 kV	CERS Moldovenească - Starokazacie
110 kV	Vasilievka- Kr. Ocnî
110 kV	Vulcăneşti - Bolgrad 1
110 kV	Vulcăneşti - Bolgrad 2
35 kV	Etulia - Nagornaia
South-West electric power system (Viniţa)	
330 kV	Bălţi - CHE Dnestrovsk
110 kV	UZ Briceni - CHE Dnestrovsk
110 kV	Ocniţa - Şahtî
110 kV	Otaci - Nemia
110 kV	Larga - Nelipovţi
110 kV	Poroghi - Soroca
10 kV	Mămăliga - Criva

Currently, the issues related to the access to the interconnection power transmission lines between Republic of Moldova and Ukraine are solved by SE „NEK Ucrenergo”. The evolution of electrical energy imports from the electric power system of Ukraine during the period 2001-2016 is presented in the Figure 2.22.

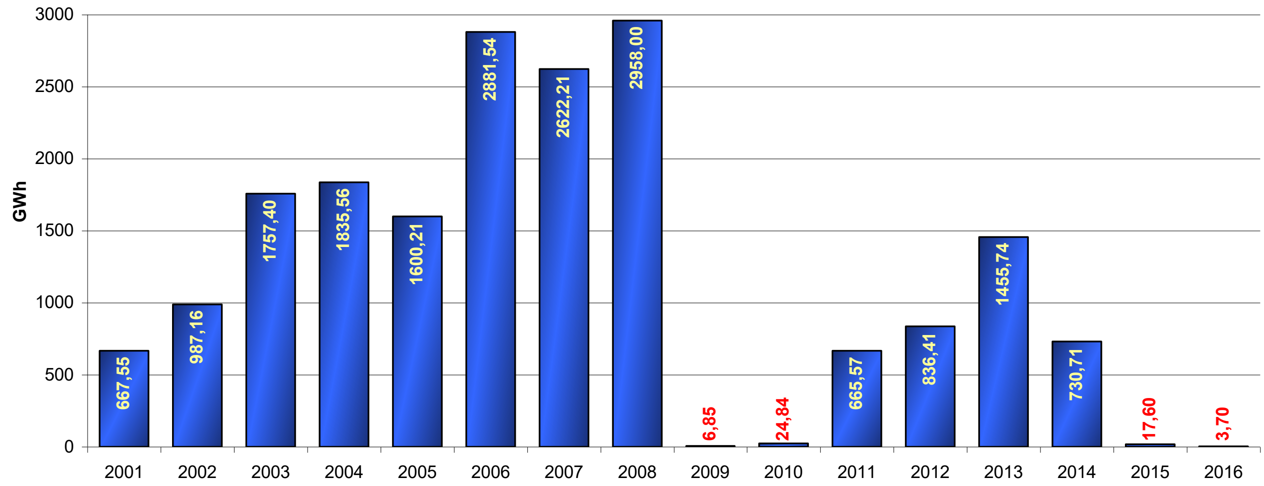

Figure 2.22 The evolution of electrical energy import from the electric power system of Ukraine

The evolution of generation, consumption, import and the total electrical energy losses during the period 2001-2016 is presented in the Table 2.4.

Table 2.4 The evolution of generation, consumption, import and the total losses of electricity

Electrical energy, GWh	Period							
	2001	2002	2003	2004	2005	2006	2007	2008
Net supply	4406,0	3914,7	3605,5	3738,8	3763,2	2465,6	3477,5	3632,7
Import from Ukraine	667,5	987,2	1757,4	1835,6	1600,2	2881,5	2622,2	2957,9
Export to Romania	-18,0	0,0	131,3	423,9	13,9	0,0	315,0	774,5
Net consumption	5102,3	4912,4	5237,0	5155,6	5355,3	5351,5	5786,2	5822,2
Electrical energy supplied to RET (right bank of Nistru)	3194,3	3266,5	3367,7	3268,2	3464,3	3661,4	3837,3	3873,6
Electrical energy supplied to electric distribuyion grid (right bank of Nistru)	3060,0	3127,5	3241,0	3128,5	3339,5	3534,2	3717,2	3748,9
Electrical energy losses	134,2	139,0	126,8	139,6	124,9	127,2	120,1	124,7

Table 2.4 The evolution of generation, consumption, import and the total losses of electricity

Electrical energy, GWh	Period							
	2009	2010	2011	2012	2013	2014	2015	2016
Net supply	5686,3	5517,0	5073,4	5071,9	3785,5	4640,5	5295,6	5091,5
Import from Ukraine	6,9	24,8	665,6	836,4	1455,7	730,7	17,6	3,7
Export to Romania	411,7	369,9	528,6	594,8	82,9	0,0	0,0	0,0
Net consumption	5283,0	5176,2	5214,9	5316,5	5162,3	5386,4	5338,8	5111,6
Electrical energy supplied to RET (right bank of Nistru)	3810,2	3927,8	4008,7	4076,2	4072,8	4118,2	4141,2	4097,0
Electrical energy supplied to electric distribution grid (right bank of Nistru)	3687,6	3790,9	3877,7	3934,4	3952,3	4005,8	4031,1	3987,0
Electrical energy losses	122,6	137,0	131,0	141,8	120,6	112,5	110,1	110,1

2.5. Power system adequacy

The term of electric power system adequacy is new to the Republic of Moldova and refers to the system capacity of permanently satisfying consumers request for power and electrical energy with due regard to the scheduled faults of system's elements and to those that may reasonably occur [2]. Basically, the main parameters that characterize the electric power system adequacy are the generation capacities, electrical energy consumption and the electrical energy interchange at the states boundaries.

System's generating units shall permanently cover the electrical energy consumption and the import/export. Thus, the generation park from an electric power system is considered to be adequate if it is able to satisfy the request of power supply in all the stationary states of system normal operation. It is worth mentioning that a big amount of renewable energy sources in Romania, namely the wind farms, is determined by a big amount of hydroelectric power plants that were built 25-40 years ago.

The electric power system's adequacy was calculated for typical days of the year 2016 for the Republic of Moldova and is presented in the Table 2.5.

Table 2.5 The electric power system's adequacy for the winter and summer typical days, MW

Nr.	Parameter	Winter characteristic day	Summer characteristic day
1	Generated power	751	514
2	Import	37	23
3	Export	0	0
4	Consumption	818	566
5	Available capacity [5=1+2-3-4]	-30	-29

2.6. Electric power system properties

2.6.1. The level of the electric transmission network's elements loading

The level of power transmission line loading can be assessed on the basis of technical criterion „thermal withstand capability", by which the conductor's temperature will rise to 70^{0} C if a current equal to the admissible current value will flow through the power line's conductors. Thus, 20% decrease of the admissible current value was considered at the stage of summer operating regimes analysis.

The assessment of power transmission level of loading was done for different scenarios in the reference year. In the Annex 3 are presented the power transmission lines with the highest level of loading that was assessed for different scenarios in the reference year. It was stated that the loading level is admissible.

2.6.2. Voltage admissible level and voltage control

The voltage level in the national electric power system for a certain range of consumption is maintained within the admissible margins by means of:

- Synchronous generators;
- On load tap changers of power transformers and autotransformers;
- Capacitor banks.

In the Table 2.6 is presented the information about voltage levels at the selected busses of the electric transmission network for the peak demand in the winter typical day of the reference year.

Table 2.6 Voltage levels at the selected busses of the electric power transmission network

Nr	Designation	Unom, kV	U, kV	Delta
34009	KALARASH	110	114,06	-2,09
36023	KOMRAT	110	109,83	-6,41
36025	LEOVO	110	110,73	-6,10
30210	KISHIN.SPP1	110	115,23	-3,21
36038	VULKANES	110	109,78	-4,59
34061	KISHINAU	330	342,29	-1,17
32027	FALESHTI	110	113,10	0,22
31008	DONDUSHENI	110	117,37	5,08
32028	FLORESHT	110	114,12	0,18
34062	STRASHEN	330	343,65	-0,31
30220	KISHIN.SPP2	110	115,33	-3,29
30250	KOSTESHT	110	116,11	3,31
30100	MGRES	330	346,00	-0,50
34022	ORHEI	110	114,93	-2,71
34020	NISPOREN	110	112,67	-2,60
36013	S.CAHUL	110	108,71	-5,92
31023	SOROKA	110	113,12	-1,17
30110	MGRES	110	115,31	-2,87
30240	BALTSISP	110	115,29	2,28
32049	BALTSI	330	347,08	4,32
30120	MGRES	400	395,16	3,07
33091	RIBNITSA	330	347,56	0,04
37041	HBK1	330	345,21	-0,95
36046	VULKANES	400	401,73	0,82
30230	DUBASARI	110	115,64	-2,40

In the Annex 3 [63] are presented the voltage values calculated for the electric power network’s 330 kV, 400 kV, and 110 kV busses at the electric power system’s boundary of Republic of Moldova. It was noticed that the obtained voltage values fall into the admissible margins for the electric power network’s busses.

2.6.3. Power and electrical energy losses

The process of generation, transmission, distribution and final electrical energy use implies as every physical system an additional consumption of power and of electrical energy called losses. The technical losses of electric transmission network are caused by different phenomena that occur in the electrical installations:

- Joule effect, due to the current flow through `power transmission lines’ conductors and power transformers’ windings;
- Eddy currents and hysteresis effect, due to the magnetic field in the magnetic core of the power transformer;
- Corona discharge, due to the electric field of high intensity of High Voltage power transmission lines;
- Ionization phenomena, due to the electric field variation in the High – and Ultra-High Voltage cables’ insulation.

The power level and structure are permanently changing for the following reasons: the variation of power generation and consumption at every buss of the electric power transmission network, the topology changing due to maintenance works or some faults that may occur in the network and bus voltage variation in the electric power system.

The power losses level is determined by:

- The power flows in the electric power networks' elements that are influenced by nodal power generation and consumption;
- The performance of the electric power network's installation;
- Meteorological factors;
- The bus voltage level.

The electrical energy losses grow with the transmitted electrical energy, the electrical distances between the generation installations and the load busses; the electrical losses become lower with voltage decrease, when atmospheric humidity is low, but could grow with the humidity.

The electrical energy losses are mostly influenced by the electrical distance between generation and consumption centers, hence – by the distribution of the electrical energy between generation units to satisfy the load, by the value and the destination of international interchanges.

The evolution of total electrical energy losses in RET is presented in percentage in the Figure 2.23.

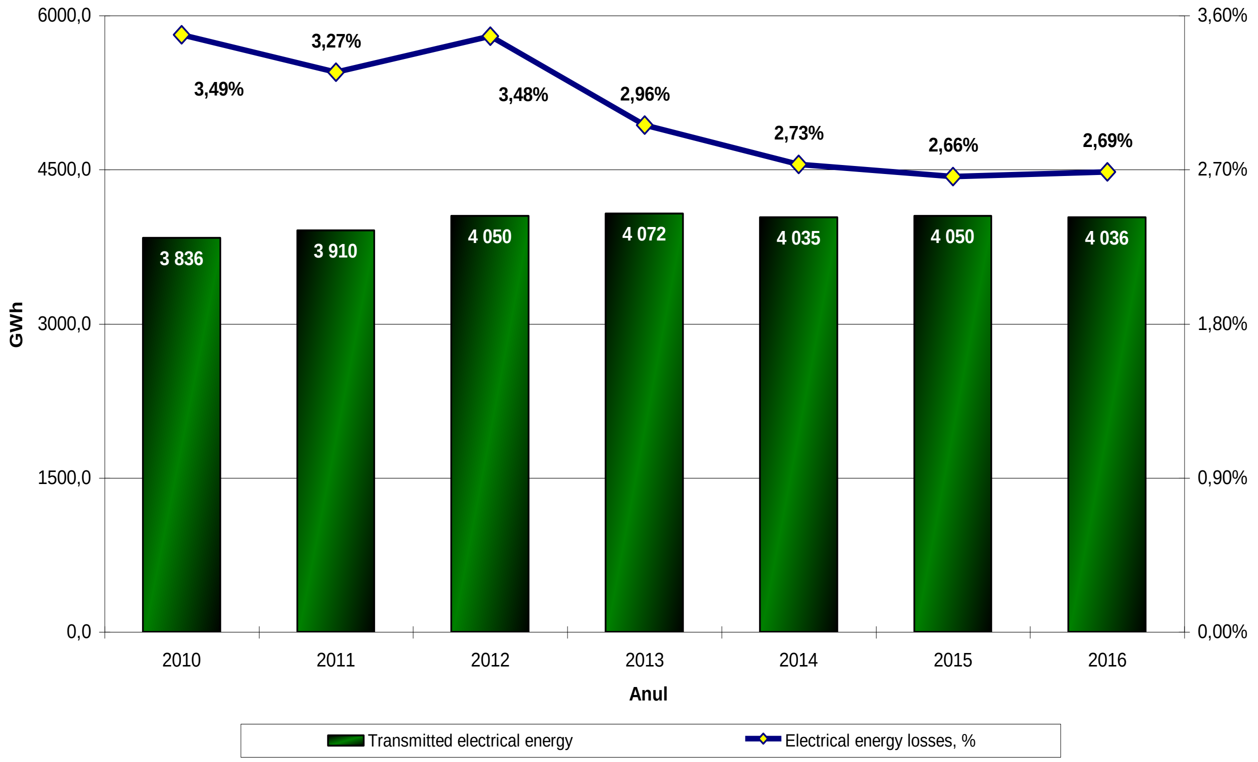

Figure 2.23 The evolution of the total electrical energy losses in RET.

2.7. Outage contingency criteria N-1 and N-2 verification

Power flow calculations were performed for RET with N, N-1 and N-2 elements in operation regarding different parts of the reference year. The choice of the RET topology with N-1 (Tale 2.7) and N-2 (Table 2.8) elements in operation was made to get the most unfavorable operating regimes of the electric power system of Republic of Moldova.

Table 2.7 The scenarios identified for the electric scheme with N-1 elements in operation

Nr.	Tripped elements
A.	Tripping 400 kV OHL „MGRES – Vulcanesti"
B.	Tripping 330 kV OHL „MGRES – Chisinau 1"
C.	Tripping 330 kV „Straseni – Chisinau"
D.	Tripping 330 kV „Balti – Straseni"
E.	Tripping the generation units at „MGRES"
F.	Tripping 330 kV OHL „MGRES – Artiz"
G.	Tripping 330 kV OHL „MGRES – Kotovsk"
H.	Tripping 330 kV OHL „Ladijensk – Kotovsk"
I.	Tripping 330 kV OHL „Adjalik – Usatovo"

Table 2.8 The scenarios identified for the electric scheme with N-2 elements in operation

Nr.	Tripped elements
A+H.	Tripping 400 kV OHL „MGRES – Vulcanesti", Tripping 330 kV OHL „Ladijensk – Kotovsk"
C+E.	Tripping 330 kV OHL „Straseni – Chisinau", Tripping the generation units at „MGRES"
D+E.	Tripping 330 kV OHL „Balti – Straseni", Tripping the generating units at „MGRES"
H+I.	Tripping 330 kV OHL „Ladijensk – Kotovsk", Tripping 330 kV OHL „Adjalik – Usatovo"

The following characteristic aspects of steady-state operation regimes with N-1 and N-2 elements in operation were analyzed:

- Electric power transmission lines loading;
- Bus voltage level in the electric transmission network;
- Variable power losses values.

In the Annex 3 [63] are presented the results of power flow calculation for the electric schemes with N, N-1 and N-2 elements in operation regarding the reference year.

2.8. Electric power system's transient state estimation

Different analyses on transient state estimation were carried out within the operational planning studies of the electric power system of Republic of Moldova for the reference year.

The national power system dynamic model is based on the equipment and control system data of power plants' generation units. The development of the external power systems dynamic model was based on the data provided by the transmission system operators, participants of specialized working group of ENTSO-E. Dynamic models of the generators from Armenia, Azerbaijan, Belarus, Bulgaria, Estonia, Georgia, Latvia, Lithuania, Romania, Russia, Turkey, and Ukraine were developed; the rest of the interconnected electric power transmission network was simplified.

Five scenarios of three-phase short circuit on the bus bars and the electric transmission lines were considered (Table 2.9).

Table 2.9 Analyzed scenarios of three-phase short circuits

Nr.	Scenario description
1.	Three-phase short circuit on the 330 kV bus bars of SS Chişinău 330/110/35 kV
2.	Three-phase short circuit on the 330 kV bus bars of SS Bălţi 330/110/10 kV
3.	Three-phase short circuit on the 110 kV bus bars of SS CET-2 110/35/10 kV
4.	Three-phase short circuit on 330 kV OHL „Adjalîk - Usatovo” (Ukraine)
5.	Three-phase short circuit on 400 kV OHL „MGRES - Vulcăneşti”

The calculations were performed considering the actions of automation systems, by means of planning and analysis software PSS/E. The results obtained due to the electric transients modeling are presented in the Figures 2.24 – 2.26 as oscillograms.

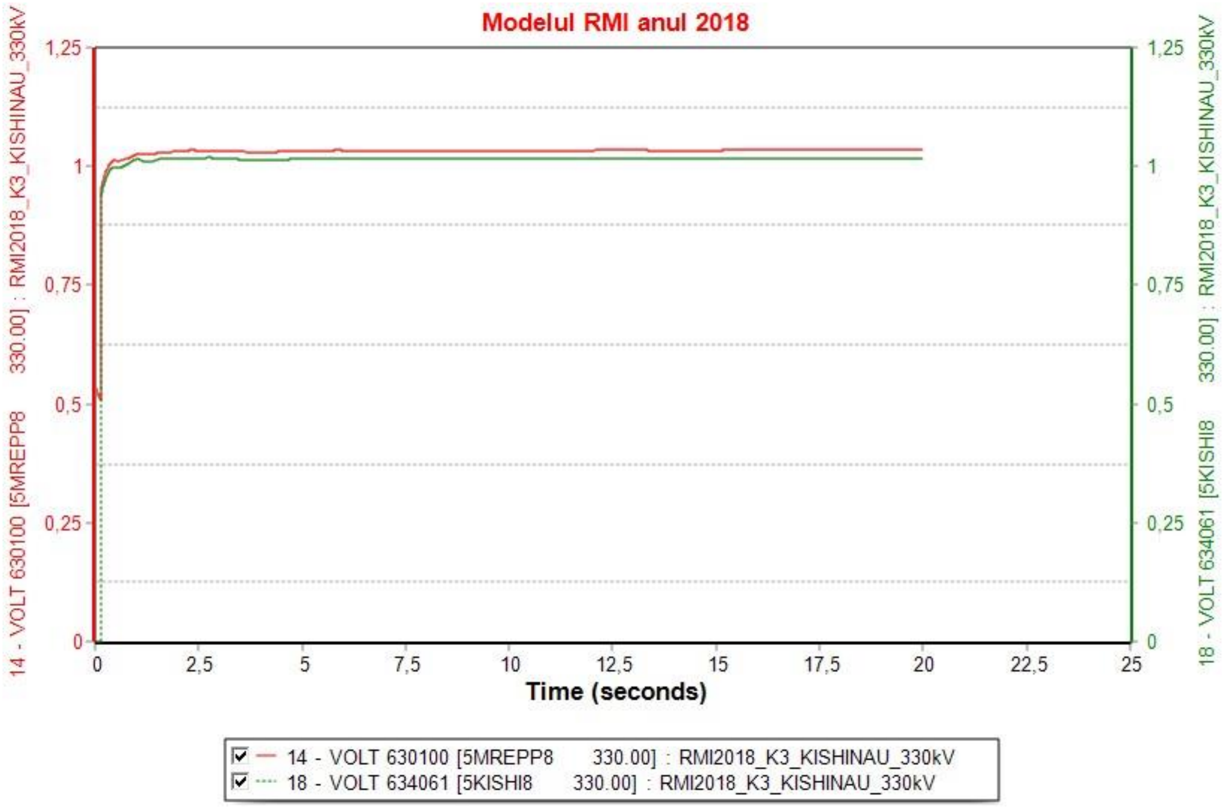

Figure 2.24 Bus voltage variations

The studies show that electric power transmission network’s bus voltages decrease with the electrical distance towards the part of the network where the short circuit occurred. The bus voltages get steady-state appropriate values after the short circuit tripping and the automatic reclose acting. It wasn’t noticed any situation when more than 0,002 ... 0,003 s were needed for voltage stabilization.

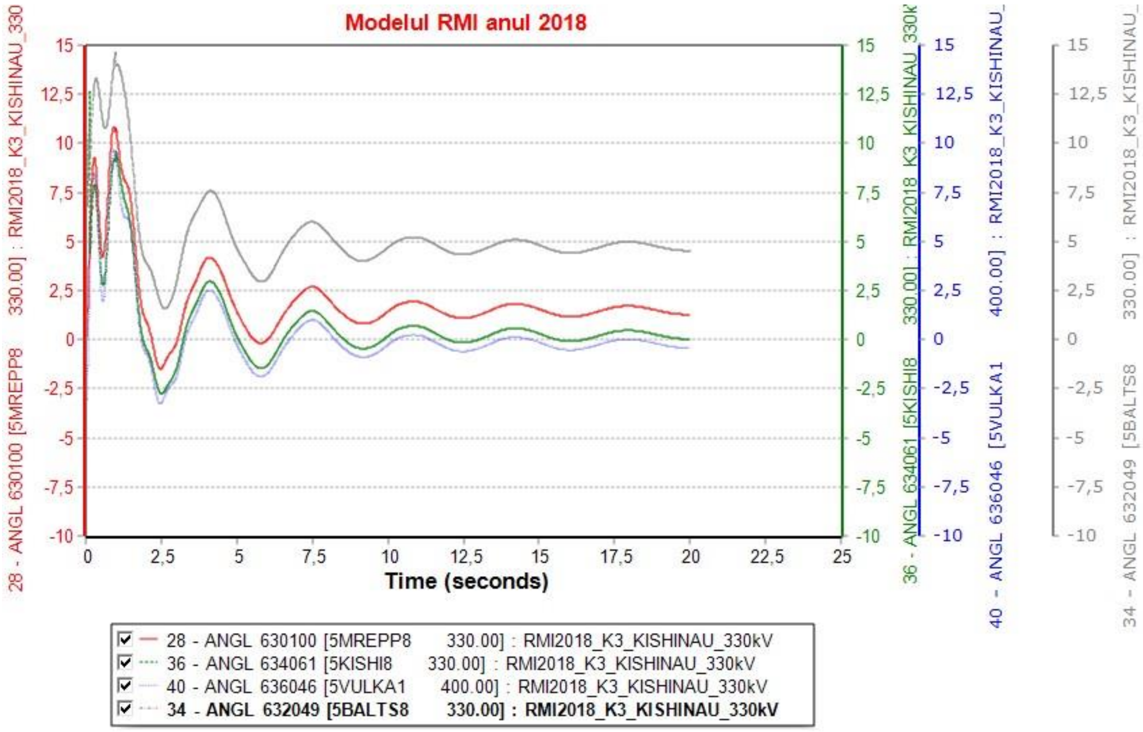

Figure 2.25 Phase angle variations

It was noticed that phase angle variations didn’t exceed 15 electrical degrees during the short circuit. Phase angles return to their steady-state values after short circuit tripping and the automatic reclosure of the tripped element (0,06 ... 0,09 s).

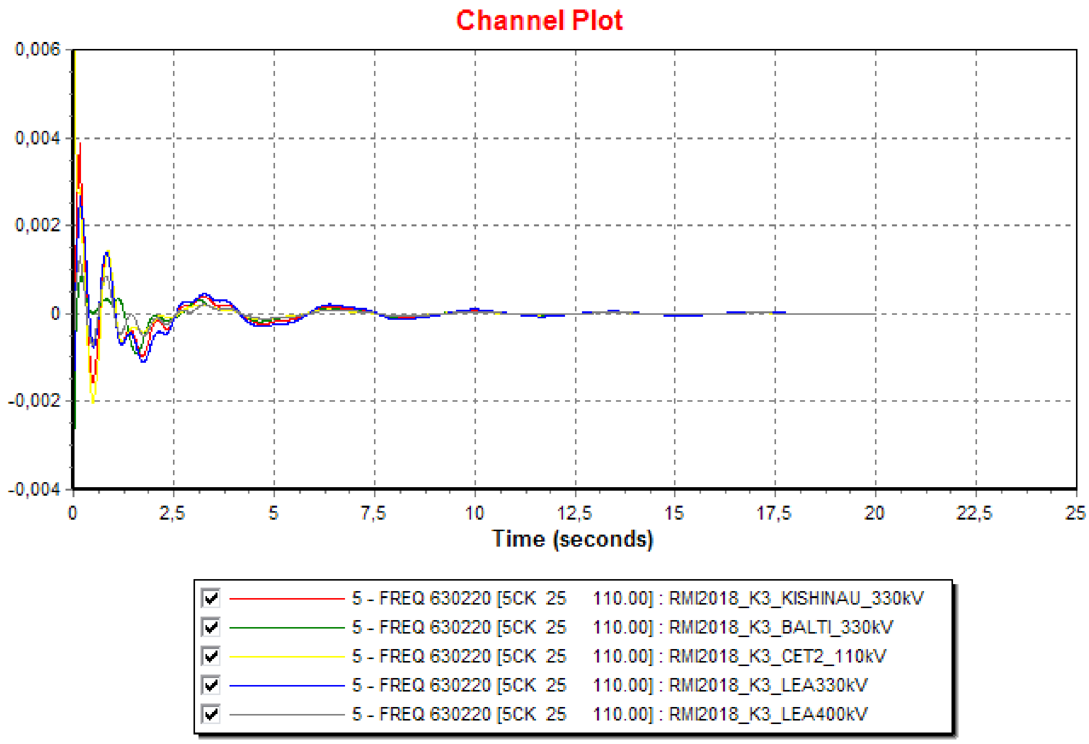

Figure 2.26 Frequency variations in SEN

Frequency oscilogramme shows that frequency deviations don’t exceed 0,1 Hz, and recovers in 5 seconds.

2.9. Performance indicators

The assessment of electric power supply quality and reliability in Republic of Moldova is stated in the Regulation on the quality of electrical energy transmission and distribution services [24]. This Regulation specifies the quality indicators for the services that are related to the power supply continuity and the quality of the relationship between the transmission system operator, distribution network operators and the costumers, as well as the consequences of the mentioned indicators noncompliance with the values set by the TSO and distribution network operators.

The TSO records/ carries out the following general quality indicators to assess the continuity of the electrical energy transmission service (Table 2.10):

a) the number of long-term power outages;
b) the total duration of the long-term power outages, expressed in minutes;
c) the ENS (Energy Not Supplied), defined as the energy that was not supplied to the customers due to the power outages;
d) the AIT (Average Interruption Time), defined as the average period of not supplying power during the year, expressed in minutes.

Table 2.10 Indicators AD, ENS and AIT for the period 2012 – 2016.

Year	2012	2013	2014	2015	2016
AD, annually transmitted energy, GWh	4219,8	5162,3	5386,4	4031,1	3987,0
ENS, not supplied energy, MWh	214,7	219,7	260,7	78,0	255,5
ENS, % of total volume	0,005	0,004	0,006	0,002	0,006
AIT, average interruption time, min/year	26,7	21,99	25,4	10,1	33,7

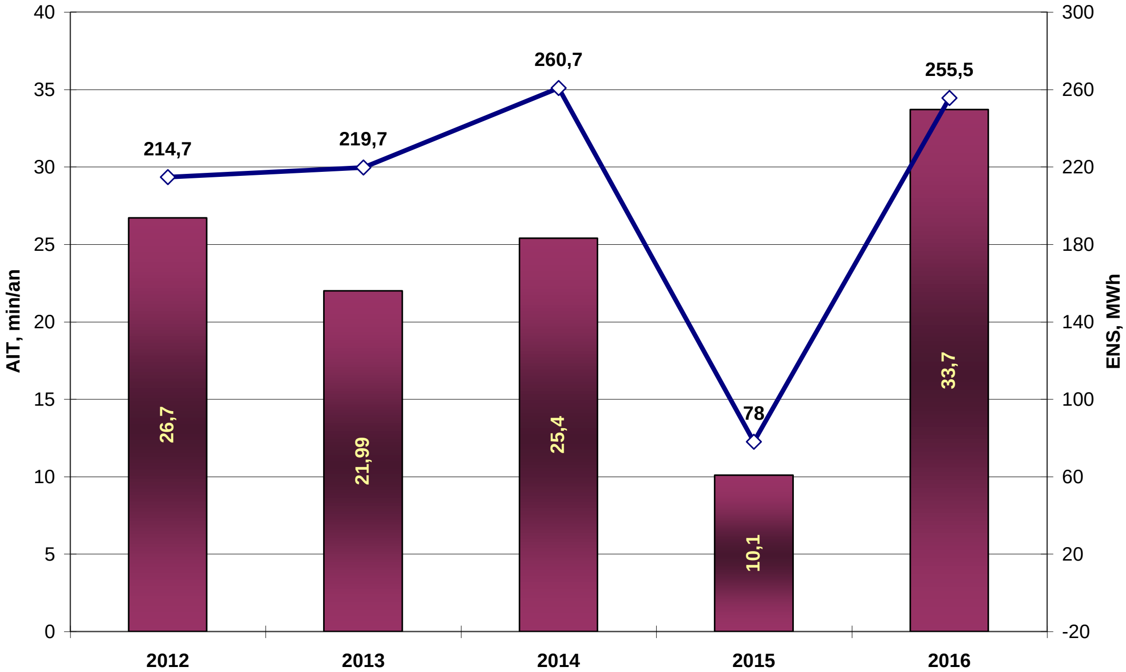

Figure 2.27 AIT indicator for the period during 2012-2016

It is cost expensive to maintain the mentioned indicators, related to the power supply continuity, at European level values for the electrical substations that were not upgraded/modernized.

2.10. Weak spots description

Electric power system functioning is permanently exposed to small and big disturbances, as: the variation of loads, active and reactive power generation, the commutation of electric power network' elements, that are considered small disturbances, as well as such regime violations as short-circuits, power cuts and scheme topology changes caused by emergency disconnections of the electrical equipment, that represent big disturbances. The electric power system exposure to different factors determines its sensitivity or the reaction to appeared disturbances reflected by AC power parameters variation, such as voltage magnitudes and angles, the power flows in all the elements and the angular speed of synchronous machines. The magnitude and the diversity of such variations depend on disturbances' magnitude and diversity, as well as on the properties of the electric power system – its topology and parameters (active resistances, conductances, different X/R ratios of power system's elements), control algorithms, control equipment properties, dynamic properties of the elements.

Power system's buses and ties that influence more its reaction to disturbances or its sensitivity by systemic and AC power parameters variation are called weak spots. As weak spots may be considered:

- a *tie* if its admittance change will lower electric power system's sensitivity;
- a *bus* if being strengthen by voltage regulation or a shunt susceptance will lower power system's sensitivity;
- a *section*, if the admittances change of all the OHLs it consists of will lower the electric power system's sensitivity as well.

An original method based on singular value decomposition (SVD) of sensitivity matrix was applied for the weak busses and ties. Different forms of inverse Jacobian matrix were considered as sensitivity matrices [63]. Its elements determine the relationship between the electric power system's elements and the spots where disturbances may occur.

Electric power system's sensitivity will rise when the minimal singular value of Jacobian matrix will tend to decrease. Therefore, it is necessary to determine the minimal singular value derivatives with respect to a controllable parameter that could be ties' admittances or bus voltage magnitudes in order to assess the influence of structural and AC power parameters of the electric network on bus sensitivity by weak spots identification.

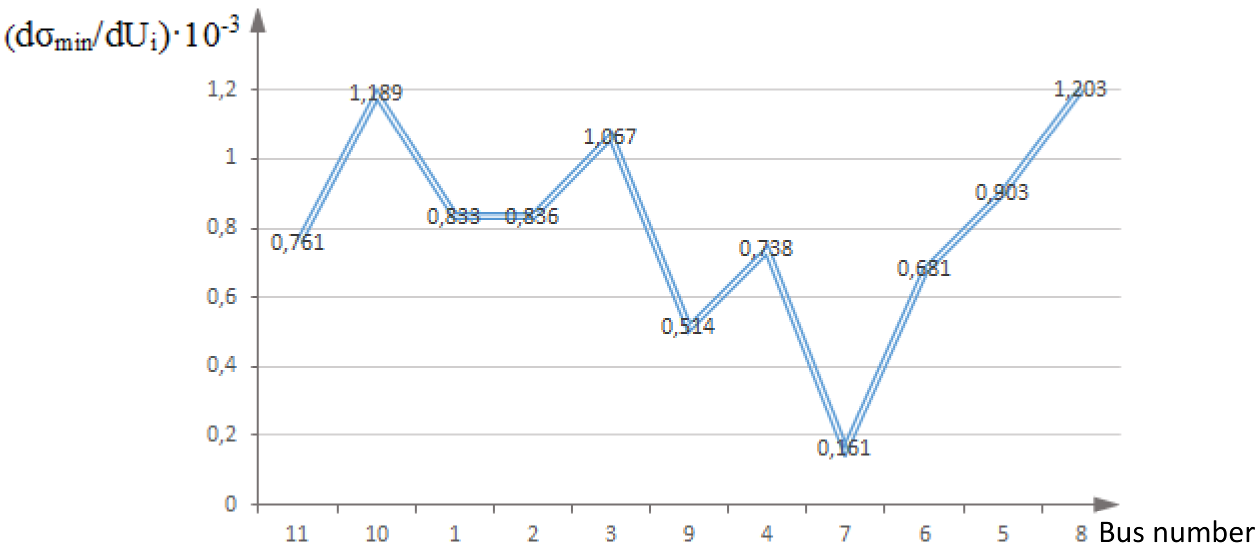

Figure 2.28 Partial derivatives of Jacobian's minimal singular value with respect to bus voltage magnitudes

Weak busses ranking by minimal singular value derivatives with respect to bus voltage magnitudes ($\partial\sigma/\partial U_i$) for the 330 kV electric transmission network of Republic of Moldova is presented in the Figure 2.28, and the weak ties ranking performed according to the above criterion is depicted in the Figure 2.29.

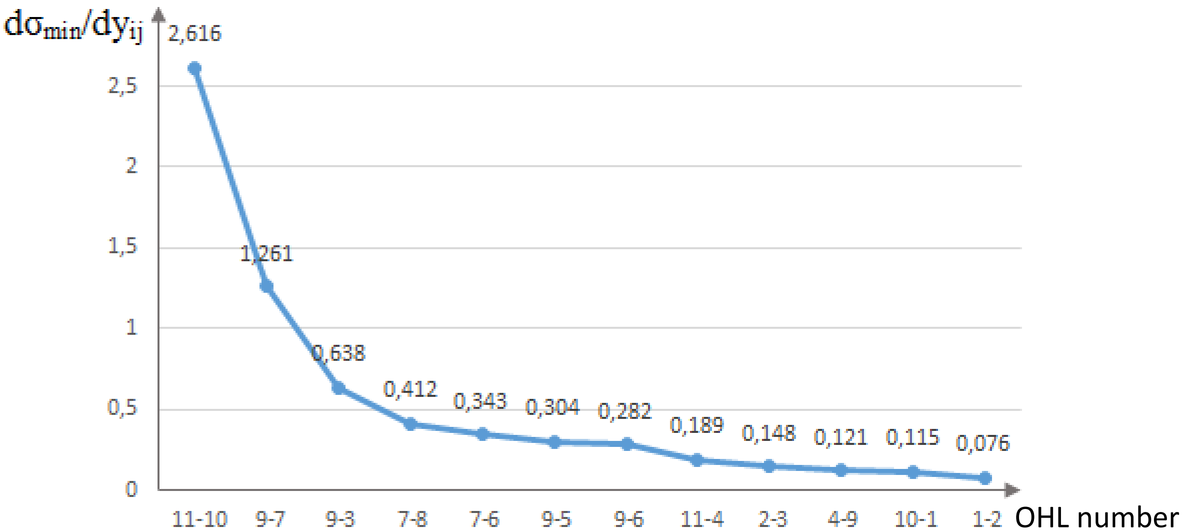

Figure 2.29 Partial derivatives of Jacobian's minimal singular value with respect to the admittances of the electric power system's single line diagram elements

The weakest busses that will mostly influence the reaction of the electric power system of Republic of Moldova to the disturbances by voltage magnitudes change are „Chisinau", „Balti" and „Straseni" according to the obtained results. The weakest ties that will mostly influence the reaction of the electric power system of Republic of Moldova to the disturbances by AC power parameters and passive elements' parameters change are the OHLs „MGRES-Chișinău" and „Chișinău-Strășeni". The OHL „MGRES-Chișinău" is mostly influenced by power system's structural parameters and is the weakest tie of the electric power system of Republic of Moldova as per above ranking.

The set of weak spots in a power system may change dramatically by loading its operation mode. However, every power system contains weak buses and ties whose weakness depends on its structural parameters that are invariant factors towards the system's operation mode.

2.11. Systems and services

2.11.1. Operative – dispatch control system - EMS/SCADA

The EMS/SCADA is related to real-time computer systems and all the necessary tools to support the relevant operational activities and functions used for the automatisation of electrical energy transmission at control rooms and dispatch centers level. EMS/SCADA improves the data delivered to the operating personnel form the dispatch centers, to the field crews for management and the entities connected to the electric transmission network, e.g. electric distribution utilities, electrical energy generation companies and others.

The EMS/SCADA provides the following major functions for the TSO SE „Moldelectrica":

- SCADA real-time control and monitoring functions (telecontrol);
- Advanced grid applications (EMS functions), including system modeling;
- Maintenance management, including the field crews and resources management;
- Works management.

The EMS/SCADA is based on the automatization, relay protection and control systems form the electrical substations. On-line data and the information about electric transmission network current state are available at dispatch centers, being collected by the RTU installed at the transmission network’s electrical substations.

Risk management:

- It may be necessary to perform an additional adjustment of EMS/SCADA applications in future. It will be necessary to test and configure the module of generation automated control when are created the conditions for its appliance.
- SE „Moldelectrica” shall test and adjust the ICCP protocol, as well as the data sharing between neighboring electric power systems.
- It is necessary to accelerate the test process of ICCP protocol and to ensure the data sharing between the EMS/SCADA systems of SE „Moldelectrica” and НЭК „Укрэнерго”.
- It is necessary to continue negotiating with„CERSM” and ГУП „ГК Днестрэнерго” on the subject of additional technical measures implementation for increasing the volume of telemetry to be transmitted to the MS/SCADA system of SE „Moldelectrica”, as well as for enhancing the telemetry quality (by installing modern converters for measuring with a high accuracy class, by decreasing the information sampling time etc).
- It is necessary to use only communication protocols of ICCP type for data sharing between EMS/SCADA systems (IEC 60870-6/NASE.2 – between the electric power systems; IEC 870-5-104 – between industrial enterprises), that were supplied with EMS/SCADA „Network Manager” system together according to contractual arrangements of the Contract 3833-A3. Cyber security standards shall be also considered.

On-line data and the information about the current state of the electric transmission network is available at the dispatch centers, that is collected by the RTUs installed at all electrical substations of the transmission network. The electric transmission network is managed and controlled by the telecontrolled circuit breakers from the dispatch centers. The EMS/SCADA systems also provide the relevant data regarding the power flows in the transmission network in steady-state functioning and in emergency regimes as well.

2.11.2. Systems of electrical energy metering and quality monitoring

SE „Moldelectrica” undertakes the following tasks to ensure the functionality of electrical energy metering and monitoring systems:

Technical maintenance of the electrical energy metering system’s components in the bounding points with adjacent electric power systems of Romania, Ukraine and ГУП „ГК Днестрэнерго”, as well as in the bounding points with electric distribution utilities (currently the metering of the electrical energy delivered to the electric distribution network is performed at the infeed 10 kV bays);

2. The checking of electrical energy metering systems compliance with the requirements of normative documents.

3. Electrical energy metering systems administration for the technical and commercial purposes:

a) taking meters’ readings;

b) the calculation and the analysis of the electrical energy losses in the electric transmission network of SE „Moldelectrica”:

- for the final, independent customers, connected to RET;
- for the electrical energy generation utilities from the electric power system of R. Moldova;

- for the electrical substations from the power systems of Ukraine, Romania and Î.U.S. „ГК Днестрэнерго” in the connection points with SE „Moldelectrica”;

c) the permissible and real values calculation and analysis regarding the electrical energy technological consumption due to electrical energy transition through the electric transmission network of SE „Moldelectrica”, in the electric grids of CET-1, CET-2– 2 and CET – Nord during their idle operation mode, in the low – and medium voltage electric lines that serve to final customers connection to the electric transmission network.

SE „Moldelectrica” shall make a sufficient and necessary investment for the modernization and refurbishment of electrical energy metering and quality monitoring systems to fulfill the requirements of the Electrical Installation Code (editions VI-VII), Metrology Law [61] and the ANRE regulations on electrical energy metering for the commercial use [62].

2.11.3. Telecomunication system

The corporative network of data transmission and IP-telephony is currently based on VPN channels leased from operators and of own power cable lines with copper conductors or fiber optic cables. The S.A. „Moldtelecom” network based on wireless CDMA technology serves for providing the channels of data transmission from metering devices and telecontrol systems „Гранит-Микро”. Ten telephonic stations ensure the automatic and dispatch communication. A reserve IP-telephony system was organized to ensure the dispatch communication.

The complex Stells Line was commissioned in 2016, which consists of 20 servers and GSM communication network sluices to record the operative telephone conversations between the operators from the dispatch centers at different hierarchical levels. Currently this complex ensures the conversations recording from different types of terminals (IP, GSM, analogous etc). The complex PHOBOS is also used for recording the conversations between dispatchers from the Central Dispatch Center by telephone station Minicom DX-500.

One hundred nineteen telecontrol units of „Гранит-Микро” type and 32 units of RTU 560 are used to integrate the objects in the telecontrol system and to transfer data to SCADA system. An information processing center based on analogous telecontrol equipment is used to transfer the data through high frequency channels from the enterprises located on the left bank of Nistru river. The large scale renovation and the installation of new digital transducers is being performed to increase the accuracy of the obtained results.

All digital telecontrol equipment is outfitted with power supply: online UPS, embedded storage batteries at DC voltage of 48 V, inverters and diesel generators. Energy storage batteries of „ELTEC” type are used additionally at 220V DC voltage as well as installations of КАУ50-220 type to supply the power at DC voltage.

2.11.4. Technological system services

Technological system services are provided by the electric transmission network users and applied by the TSO to perform:

a) the compensation of power system’s load variation, frequency control and balance regulation;

b) the compensation of the differences regarding the power system functioning programme, thus maintaining the active power reserve capacity;

c) bus voltage regulation in the electric power network;

d) compensation of the technological consumption in the electric transmission network;
e) the restoration of power system functioning after a collapse related to the whole system or to a specific area.

Technological system services are performed by the following resources:

a) frequency primary control systems;
b) frequency-power secondary control systems;
c) automatic systems of load automatic shedding;
d) local systems of voltage regulation;
e) automatic systems of generation units isolation in regard to the auxiliary supply and selfstarting to restore the power system’s functioning after collapse of the whole system or any area;
f) the dispatch customers that can reduce their load or can be cut out by the TSO in case of a bilateral agreement.

The relative value of annual electrical energy generation amounts to 0,0391 in comparison with the annual production in CIS and Baltic countries. Thus, frequency correction factor will be equal to 82 MW/Hz, the mandatory primary annual reserve shall be ±5 MW and the charging/discharging reserve shall amount to +240 MW / –100 MW [51].

It has to be mentioned there is no secondary legal framework on balance market functioning in the Republic of Moldova, and no electric transmission network’s users on the right bank of Nistru river to provide system services. The mentioned issue will get worse with wind and solar power plants connection to the public grid. These types of power plants have significantly different technical and maintenance properties to other power plants, especially due to random values of available power in every moment, that may vary between 0 and the installed power depending on metrological factors.

Therefore, it can be stated that is necessary:

- to develop the secondary legal framework regarding the balance market functioning;
- to develop a study on balance power assessment based on the total power of wind and solar power plants connected to the electric public grid;
- to support the traders willing to build gas turbines based power plants with a very short starting time (5-30 min).

Presently the frequency control is provided by the electric power systems of Russia and Ukraine, and the power flows through the interconnection ties is controlled manually by dispatch provisions sent by phone. A secondary control system does exist within the automated management system, but it can’t be used before a balancing mechanism will be set regarding the actual energy market conditions while there are no system service providers on the market. It is expected that the balancing mechanism (the balance power and energy reserve) will be introduced, as well as the rest of the system service components at further stage of electrical energy market rules review.

It is necessary to fulfill the requirements of the Operational Handbook, especially The Policy No.1 regarding the primary, secondary and tertiary control, in the light of the agreement of the power systems of Ukraine, of Republic of Moldova and ENTSO-E interconnection.

The national electric power system of Republic of Moldova will be considered as a CONTROL AREA according to the fact that the power systems of Ukraine and Republic of Moldova will represent a unique CONTROL BLOCK. Thus, it is accepted to import at most 50% of the necessary reserve amount from neighboring countries to provide the secondary control.

3. TRANSMISSION GRID DEVELOPMENT SCENARIOS FOR THE 2018-2027 PERIOD

3.1. General principles for scenario building

The purpose of transmission grid development planning is to maintain the quality level of transmission and system services as well as power system security, as required by the provisions of enforced regulations, in an economic efficient manner.

Perspective-based scenario building implies the following analysis stages:

- Electricity demand forecast;
- Electricity demand and load forecast of absorbed power (active and reactive) for typical frames of the load curve (maximum and minimum load for the winter and summer seasons) for each substation;
- Electricity import forecast;
- Evaluation of active and reactive balance for each node of transmission grid, for each frame of typical load curve for minimum and maximum regimes;
- Evaluation of losses in transmission grid;
- Ensuring voltage stability and within limits, for transmission grid nodes, by usage of existing regulation means and by planning for any required development;
- Checking for N-1 and N-2 criteria for different regimes of the power system;
- Evaluation of power system dynamic stability on different disturbances;
- Evaluation of technical condition of transmission grid equipment owned by TSO;
- Reliability indicators calculation for transmission grid nodes;
- Establishing of actions and strengthening measures (new projects) that are necessary for ensuring grid adequacy and transmission service performance;
- Establishing of technical and economic optimal solutions for modernization and development of transmission grid and measures for reducing environmental impact;
- Prioritizing and establishing of programs for implementation of modernization/ development of transmission grid and related infrastructure;
- Identification of financing sources for investments included in transmission grid put.

Transmission grid development is performed taking into consideration the requirements and priorities established in Energy Strategy till year 2030 [29]. These are key references regarding identification of priority directions.

3.2. Computational models

In order to perform the calculations and transmission grid regimes analysis, for the reference year (year 2018), computation models have been set-up for specific scenarios:

- Winter maximum (RMI);
- Summer maximum (RMV);
- Summer Off-peak (GMV).

Several perspective horizons have been set-up for which the calculations would be performed as well as the transmission grid working regimes analysis, based on 2030 Energy Strategy provisions:

- year 2020 (Year0 + 2);
- year 2022 (Year0 + 4);
- year 2027 (Year0 + 10).

The scenarios used for identification of transmission grid development needs have been developed by experts of TUM after consultations with specialist from SE Moldelectrica, starting from available information regarding transmission grid from TSO, transmission grid users, other involved parties as well as TSOs of neighboring countries.

Base scenario involves forecasts for consumption, import and local production, based on most plausible information available at the stage of development of the Development Plan.

For base scenario, models have been set-up for typical frames of consumption for reference year (RMI, RMV, GMV), but for the perspective scenarios, fore each time horizon as a reference winter maximum regime (RMI) would be used: reference year +2 year, reference year + 4 years and reference year +10 years.

Alternative scenarios would take into account different hypothesis regarding the following:

- Consumption increase rate;
- Electricity interchange between national and neighboring countries power systems;
- Construction of new power plants.

A reasonable amount of alternative scenarios would be taken into account for different frames of the load, which are to add to the conclusions of the analysis for the base scenario. These scenarios have the following roles:

- To estimate the flexibility of the identified solutions for grid development against many other possible evolutions;
- To offer criteria for further adjustment of the development plant depending on evolutions within the system.

3.3. Perspective scenario development

3.3.1. Scenarios used for analysis of transmission grid development needs

The main drivers for identification of needs and priorities for investment projects that are included in ten-year Development Plan are:

- Current technical condition of electrical equipment (physical and moral wear of the equipment which are in use for more than 30 years and which is more than 65%);
- as there is a whole park of old equipment that is moral and physical obsolete, a priority for SE Moldelectrica is investment in modernization and filling out of diagnostic, control and measuring equipment;
- reconstruction of existing OHL due to enforcement of provisions of 7th edition of NAIE (Norms for installation of electrical equipment) that includes modifications for wind dynamic pressure and rime thickens zones;
- replacement of damaged towers that have been identified as a result of technical economic analysis of electric lines;
- reconstruction of some portions of 110kV OHL that cross or are located on the territory of Ukraine and for which periodic verification, maintenance and repaired works are difficult to perform;
- telemetry and remote control for all transmission grid substations;
- continuously increasing costs for maintenance of protection and automatics that are based on electro mechanic relays and which should be replaced with ones that are based on microprocessors;

- modernization and reconstruction of electricity measuring systems in order to fulfil the requirements of normative framework in the field of metrology and electricity measurement for commercial purposes;
- environment aspects related to the need for minimization of usage of oil filled equipment (especially breakers);
- continuously increasing costs related to fuel, that requires replacement of vehicles, machinery and special mechanisms;
- minimization of maintenance costs for buildings and constructions by setting up of energy efficiency programs for buildings;
- minimization of maintenance costs for transmission grid;
- reduction of loses in transmission grid;
- environmental and social impact;
- feasibility of technical solutions for identified investment projects.

3.3.2. Scenarios for electricity consumption evolution in national power system

For electricity consumption evolution forecast for 2018-2027 period, that has been used for calculations and analysis of working regimes of transmission grid and that are the basis for development of the 10 year development plan, the following have been taken into consideration: forecasts that are presented in energy strategy till year 2030, available macroeconomic forecasts including GDP evolution [29], electricity consumption evolution for the 2001 – 2016 period presented by ANRE [52-59], as well as requests of transmission grid users for 2018-2027 [45-50].

In the Figure 3.1 are presented the existing scenarios regarding electricity consumption evolution for the 2011 -2030 period.

By comparing the values of electricity consumption for the year 2016, we can observe that the forecast presented in the energy strategy till the year 2030 shows considerable difference from the real value that is presented in ANRE Report in year 2016 [59] and the difference is 884.7 GWh.

For these reasons it shall be chosen for the values presented by ANRE as basis for reference scenario establishment.

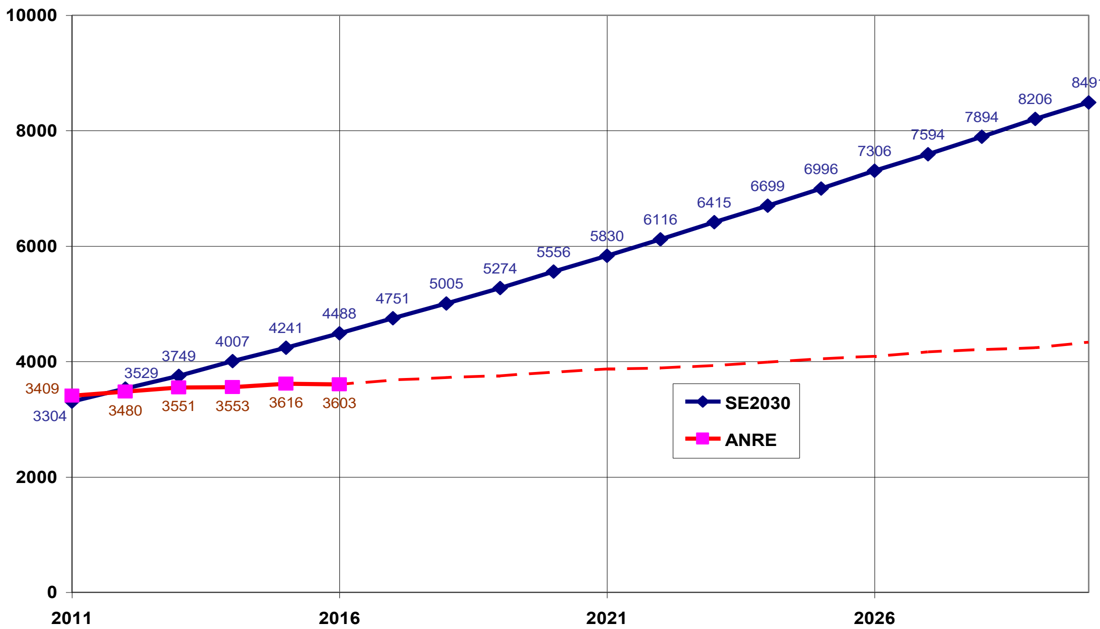

Figure 3.1 Existing scenarios regarding electricity consumption evolution, GWh

Starting from the reference scenario it shall be analyzed more two scenarios regarding electricity consumption evolution (winter maximum load RMI), taking into consideration a possible increase/decrease by 5% against the reference scenario (Figure 3.2 and Table 3.1).

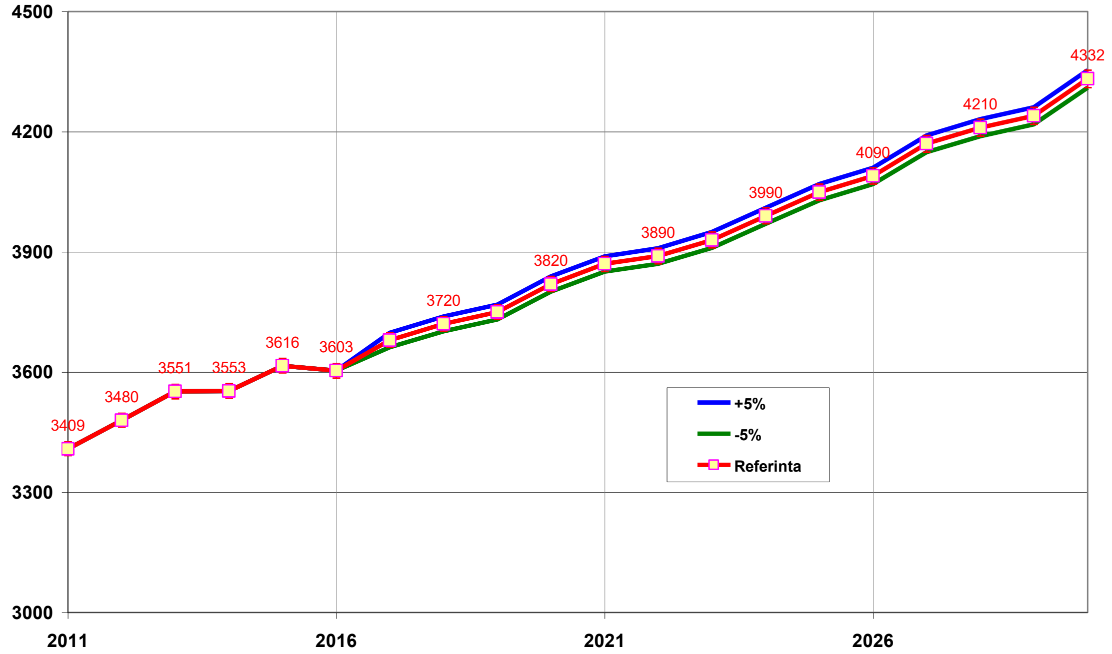

Figure 3.2 Developed scenarios regarding electricity consumption evolution, GWh

Table 3.1 Typical frames

Year 2020 (Year0 + 2)			Year 2022 (Year0 + 4)			Year 2027 (Year0 + 10)		
-5%	Reference	+5%	-5%	Reference	+5%	-5%	Reference	+5%

3.3.3. Scenarios regarding electricity production evolution

From the analysis of the data presented in Table 2.4, regarding participation evolution of power plants from the right bank of Nistru river, in covering of the total electricity consumption for the 2001 – 2016 period, it can be seen the existence of a pronounce concentration of electricity production of two actors on the electricity market, with a cumulative participation that varied from 67.4% in year 2001 up to 81.3% in year 2016.

It should be mentioned that practically all existing electricity producing units have an exceeded their life span (Table 3.2).

Table 3.2 Electricity sources from the right bank of Republic of Moldova

	Electricity source	Installed electric power, MW	Commission year
1.	CHP-1, Chişinau	66,0	1951-1961
2.	CHP-2, Chişinău	240,0	1976-1980
3.	CHP-Nord, Bălţi	20,4	1956-1980
4.	HPP Î.S. „Nodul Hidroenergetic Costeşti"	16,0	1978
5.	CHP of sugar production facilities	97,5	1956-1981
6.	Small renewables power plants	6,9	

Taking into account the above mentioned, in Energy Strategy of Republic of Moldova till year 2030 is mentioned that the installed electricity generating capacities in Republic of Moldova is premise for establishment of a platform for electricity generation. The Energy Strategy proposed goal for year 2020 is extension of existing capacities with 800 MW. This is to be done by decommissioning of 250 MW from CHP-1 and CHP-2 and construction of new capacities with installed total capacity of 1050 MW. It is envisaged construction of a new power plant in Chisinau with an installed power of 650 MW, based on efficient technologies for electric and thermal energy generation. Extension of CHP-North shall be analyzed depending of thermal load. It should be mentioned that from those 1050 MW, about 400 MW are to be renewable sources (wind, solar).

Regarding current status of intentions for construction of new generating facilities, for the next 10 years, based on grid connection permits issued by grid operators as well information provided by electricity producers at the request of SE Moldelectrica, there is an interest for a total power of 1357.26 MW (renewable sources) and CHP-North plans to install additional 13-16 MW.

It should be mentioned that S.A. „Termoelectrica" requested that the modernization plan for existing capacities (new capacity, modernization of existing) to be presented at a later stage, after finalization of the study regarding development strategy of new capacities [50].

Evolution of renewable energy sources

A specific element for the current stage is the interest for usage of renewable energy sources: biomass, solar and especially wind energy.

Transmission grid integration of renewable energy sources (RES) is done by SE Moldelectrica by issuing grid connection permits.

RES integration, inevitable will lead to increase of distributed generation of electricity, that on its turn shall lead to the need for taking into account of the particularities of distributed generation at the level of power system of Republic of Moldova. In this regards, 3 scenarios have been set-up for gradual integration of RES in power system, for the period of 2018-2027 (Table 3.3), which are based on provisions of energy strategy till year 2030 [29].

Table 3.3 RES Power system integration

Region \Year	2020	2022	2027
North	-	50	150
Center	50	100	150
South	150	250	300
TOTAL, MW	**200**	**400**	**600**

One of the priority task of SE Moldelectrica as TSO is ensuring the reliability and security of the system during integration of new distributed electricity sources.

Worldwide practice on this matter is establishment and use of typical requirements for all distributed electricity sources.

On the other hand, according to national legislation, it is the duty and obligation of renewable electricity producers to use for distributed generation of machinery and equipment based on best technologies that fulfill all requirements and comply with all norms.

On the same time the use of old used machinery and equipment can negatively influence the power system, locally as well as system wide.

In order to monitor and constantly estimate the impact of distributed generation on national power system it is important to obtain detailed information related to distributed generation at issuing grid connection permits and periodic information updates, that leads to necessity of requesting the information from distribution companies, on distributed electricity sources connected to distribution grid. The relevant and necessary information for analysis and that are to be requested from distribution grid operators includes installed power, type of installation, connection point and other information for distributed sources with an installed power of above 100 kW.

It is to be noted, that at this point there are no normative documents regarding RES and as such it is necessary that all involved parties use as a guide the TSO's requirements along with ENTSO-E network codes.

3.3.4. Electricity exchange scenarios

Energy Strategy of Republic of Moldova till year 2030 envisages diversification of electricity supply sources by getting access to the internal electricity market of EU and this can be accomplishing only by interconnecting the power system of Republic of Moldova with power system of Romania. In perspective, the benefit is the possibility of accessing a larger electricity market, which would not be possible for Republic of Moldova without a synchronous/asynchronous interconnection of SE Moldelectrica's grid to the continental power system of ENTSO-E.

Interconnection to EU system offers beside of an increased security as well potential biter wholesale prices due to increase in competition which might lead to a less burdensome price of electricity for the final consumer. As such there is major need for new high voltage lines for interconnecting power systems of Republic of Moldova and Romania.

According to Energy Strategy of Republic of Moldova, the following Back-to-Back interconnection options have been analyzed:

1. 400 kV OHL Isaccea – Vulcăneşti – Chişinău;
2. 400 kV OHL Bălţi – Suceava;
3. 400 kV OHL Străşeni – Ungheni (an auxiliary line for increasing the transit flow through internal grid) and 400 kV OHL Ungheni – Iaşi.

It should be mentioned that use at maximum capacity of 400 kV OHL Bălţi – Suceava project has as a precondition the construction of 400 kV OHL Suceava – Gădălin, that is included in Romanian grid development plan for Romanian [2, p.155].

Congestion on interconnection Moldova – Ukraine limits the electricity import and transit. A second 330 kV OHL Bălţi – HPP Dnestrovsk might be an additional project aimed at increasing the possibility of import from Ukraine. At this stage this projects are not to be included in 10-year development plan as first of all it has not been included in Ukraine development plan for the period 2016-2025 and in the second, a Study developed by department of EE from TUM [30] has shown that a second line Bălţi – CHE Dnestrovsck had not improve the working regimes of transmission grid at that stage.

Taking into consideration the above mentioned and priorities of Energy Strategy of Republic of Moldova till year 2030[29], the following projects have been included in the development plan for the following 10 years, in the section „Interconnection with neighboring systems".

Table 3.4 Investment projects for interconnection with neighboring systems

Nr.	Investment projects for interconnection with neighboring systems
1.	BtB station of 600 MW at Vulcăneşti
2.	Extension of 400 kV switchyard in SS Vulcăneşti 400 kV
3.	Construction of 400 kV switchyard and extension of 330 kV switchyard in SS Chişinău 330 kV
4.	Construction of 400 kV OHL Vulcăneşti - Chişinău
5.	Construction of 400 kV OHL Bălţi - Suceava

Figure 3.3 Scenarios regarding construction of interconnection lines

3.3.5. Perspective regions for new electricity sources

Identification of perspective regions for new electricity sources as well as implementation timeframes and locations can be done by taking into consideration the following aspects:

- Local consumption and possibility for covering it;
- Increase rate of the consumption for a period of 10 years;

- Number of connection permits for each transmission grid node;
- „Access grids” (the ones with minimum construction cost).

Figure 3.4 shows regions of interest for construction of power plants based on renewable energy sources as from the grid connection permits issues by SE Moldelectrica.

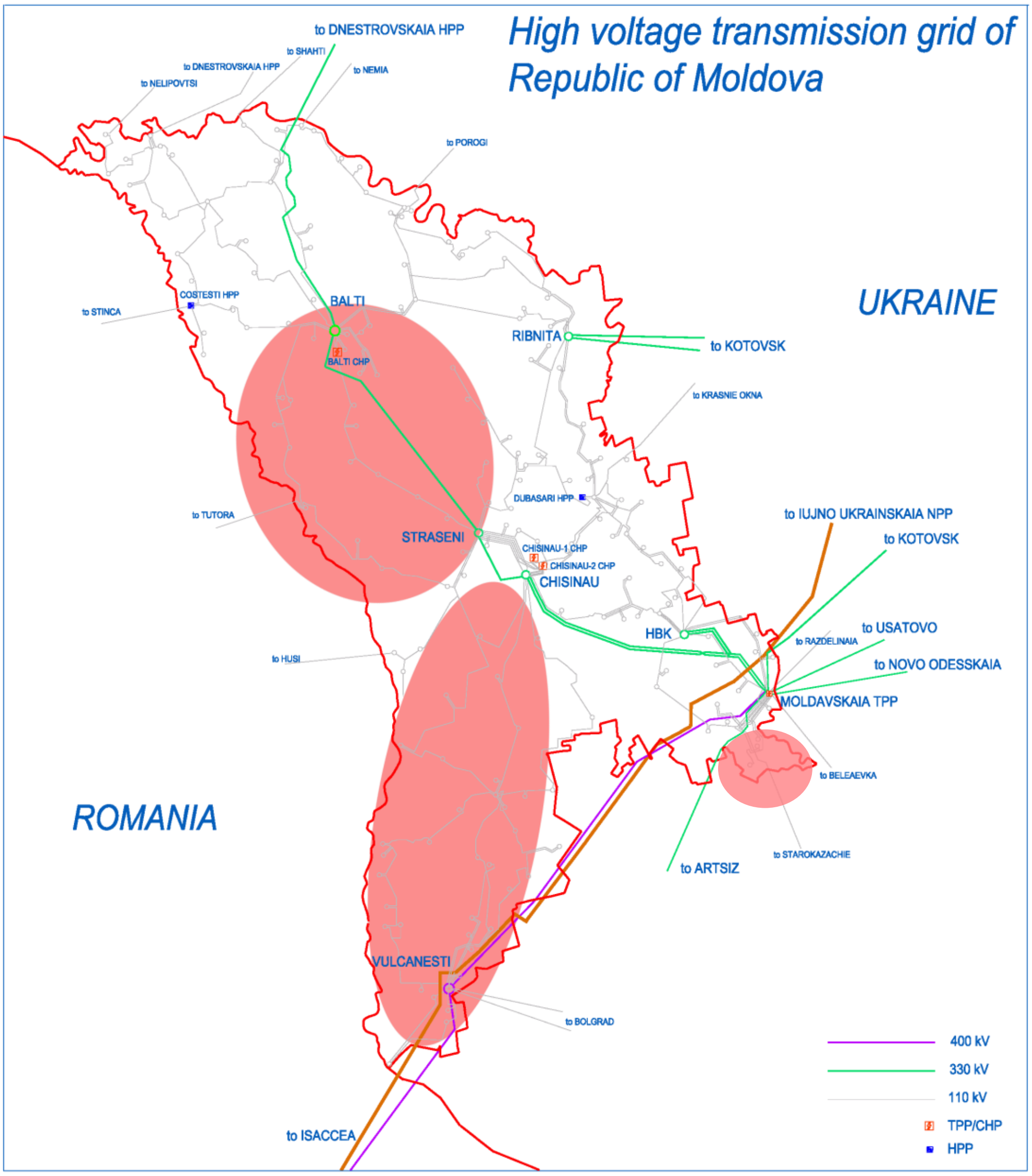

Figure 3.4 Interest zones for connection of renewable electricity sources

4. ANALYSIS OF TRANSMISSION GRID WORKING REGIMES

4.1. Load flow regimes

In order to identify the needs for transmission grid development, a set of studies have been performed with for verification of 2018-2027 working regimes of Republic of Moldova electricity transmission grid. It should be mentioned that it has been taken into consideration scenarios regarding development of production fleet, interconnections with neighboring countries, as well as development of electricity transmission grid.

The following characteristic aspects of working regimes have been analyzed:

- Electric lines loading within transmission grid with N, N-1 and N-2 elements in operation;
- Voltage levels at transmission grid nodes with N, N-1 and N-2 elements in operation;
- Level of active power losses in electricity transmission grid;
- Verification of fulfillment of N-1 and N-2 security criteria;
- Transient stability of power system.

Calculation of load flow regimes have been carried out by considering interconnected synchronous operation with IPS/UPS powers system (interconnection with PS of Ukraine) and asynchronous operation, via Back-to-Back stations, with ENTSO-E continental power system (interconnection with PS of Romania).

4.2. System adequacy

Adequacy of PS of Republic of Moldova has been estimated in scenarios described in chapter 3.2 and presented in Tables 4.1 – 4.2.

Table 4.1 System adequacy in different scenarios for year 2018, MW

#	Parameter	WMAX	SMAX	SMIN
1	Generated power:	1256	976	378
1.1	Thermal power plants (TPP)	956	904	306
1.2	Combined Heat and Power plants (CHP)	256	37	37
1.3	Hydro power plants (HPP)	44	35	35
2	Load (without losses)	1220	943	348
3	Available capacity (without import/export) [3=1-2]	36	33	30

Table 4.2 System adequacy in RMI scenarios for years 2020, 2022 and 2027, MW

#	Parameter	2020	2022	2027
1	Generated power:	1284	1018	911
1.1	Thermal power plants (TPP)	784	318	11
1.2	Combined Heat and Power plants (CHP)	256	256	256
1.3	Hydro power plants (HPP)	44	44	44
1.4	Renewable electricity sources (RES)	200	400	600
2	Load (without losses)	1252	1283	1363
3	Import (trough BtB stations)	-	300	500
4	Available capacity [4=1-2+3]	32	35	48

By analyzing the above data, it can be concluded that in reference regimes, the power system of Republic of Moldova can meet the adequacy requirements and the available capacity is enough to cover the electricity losses.

4.3. System characteristics

4.3.1. Loading level of electricity transmission grid elements

Evaluation of loading level of transmission electric lines has been performed similarly to calculations performed in chapter 2, by using as technical criteria the „admissible heating".

From the analysis of obtained results it can be concluded that there is a set of electrical lines that have the tendency for overloading above admissible level in majority of scenarios. The detailed information, with overloaded elements marked, is presented in Annex 4 [63] and in Table 4.3 is presented the information related to some electrical lines for characteristic frames.

Table 4.3 Loading level of electricity transmission lines, %

Year	2020			2022			2027		
OHL \ Scenario	*-5%*	*Ref.*	*+5%*	*-5%*	*Ref.*	*+5%*	*-5%*	*Ref.*	*+5%*
XU1BOLGR - UBOLGR51	75,7	74,7	73,8	95,1	93,9	92,8	102,5	101,3	100,1
_CHOKANA - KISHIN.SPP2	60,4	61,7	63,0	56,6	57,8	59,0	62,9	64,3	65,6
_HOLODMA - STRASHEN	48,8	51,2	53,6	46,7	49,1	51,5	56,7	59,3	61,9
IALOVENI - KISHINAU	42,7	45,2	47,6	44,7	47,3	49,8	46,2	48,9	51,6
NISPOREN - BOBEIKA	39,3	38,4	37,6	40,3	39,5	38,8	55,3	54,7	54,0

It should be considered the fact that actual working regimes might differ significantly from the analyzed ones as a result of continuous change of load, production and exchanges on interconnection lines, as well as due to scheduled outages for maintenance or unplanned outages. This can lead to different loading of grid elements.

In order to cope with disturbances, a reserve is needed, as the grid elements should to be able to withstand the additional load.

4.3.2. Voltage admissible level and voltage regulation

After performing the load flow calculations for characteristic frames it has been identified that the voltage levels at transmission grid nodes are within admissible limits. In order to confirm this, a set of power system nodes, for different voltage levels, have been selected and presented in Table 4.4.

Table 4.4 Voltage levels in selected nodes of electricity transmission grid, kV

Year	2020			2022			2027		
Node \ Scenario	*-5%*	*Ref.*	*+5%*	*-5%*	*Ref.*	*+5%*	*-5%*	*Ref.*	*+5%*
BALTSI 330 kV	348,0	347,4	346,7	349,4	349,0	348,6	349,1	348,7	348,3
MGRES 330 kV	346,4	346,1	345,8	346,7	346,6	346,4	342,3	342,1	341,8
VULKANES 400 kV	408,3	408,1	407,8	408,1	408,0	407,7	403,7	403,4	403,1
KISHIN.SPP2 110 kV	115,7	115,4	115,1	116,0	115,8	115,5	115,2	114,9	114,7

The results regarding voltage values calculated for transmission grid nodes of 330kV, 400kV as well as 110kV located at the borders of PS and for perspective scenarios, are presented in Annex 4 [63].

4.3.3. Electricity and power losses

Variable electricity and power losses in different working regimes can vary significantly from the calculated ones for the reference regimes due to power flow modifications trough electricity transmission grid elements. The presented results for reference regimes show that with increase of consumption there is an increase of variable power losses in transmission grid, but a possible increase/decrease of consumption with 5% from the forecasted reference regime, leads to a different modification of variable losses in transmission grid from the left and right banks of Nistru River (Figure 4.1).

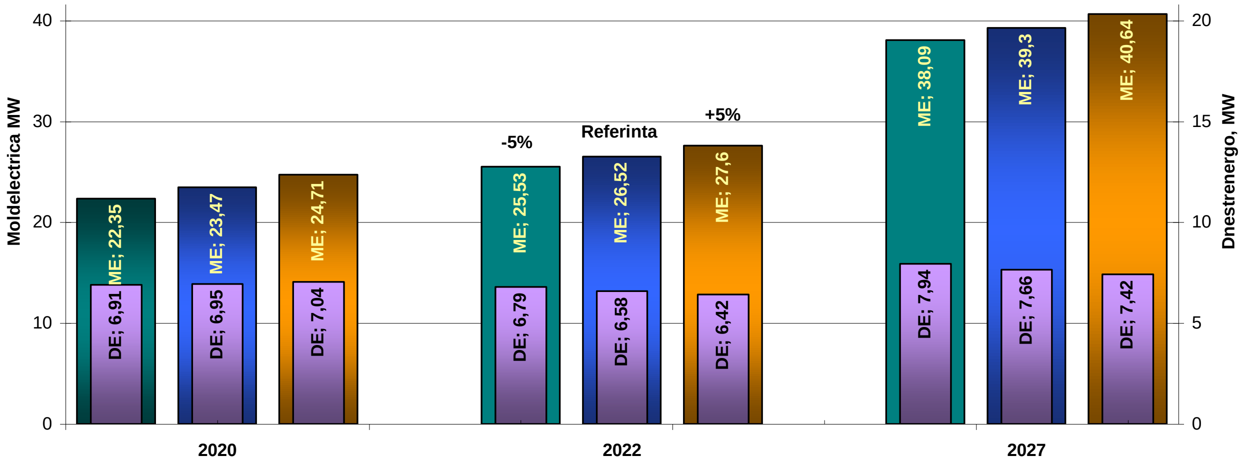

Figure 4.1 Evolution of active power variable losses in transmission grid

Variable power losses in transmission grid elements, for different forecasted scenarios, are shown in Annex 4 [63].

4.4. Verification of N-1 and N-2 security criteria

Figures 4.2 – 4.4 show the results of load flow calculations for N-1 configurations of the electrical scheme and Tables 4.5 – 4.7 show the results of load flow calculations for N-2 configurations.

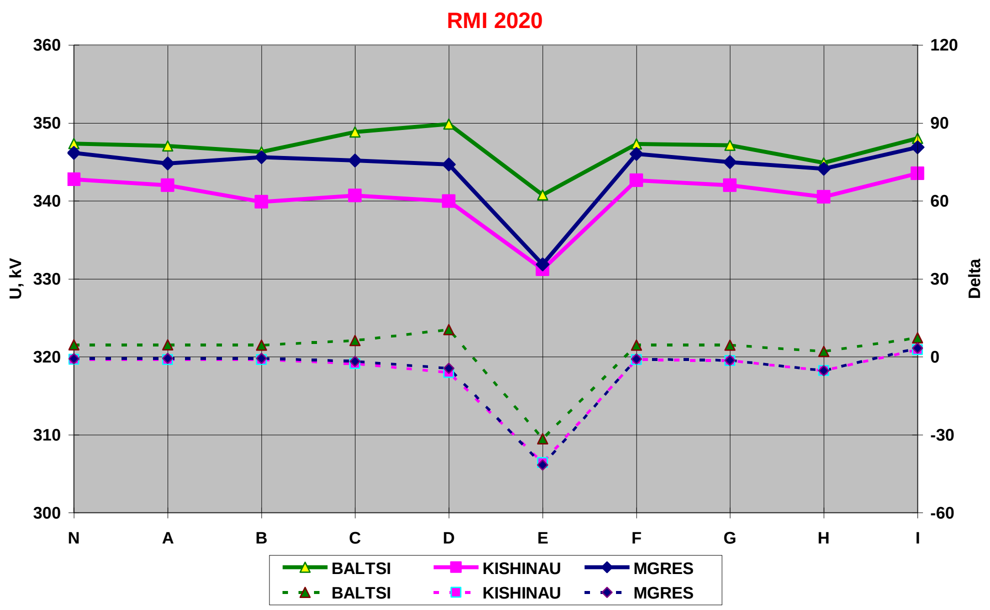

Figure 4.2 Voltages and angles in transmission grid nodes, with N-1 elements in operation, for calculation model for year 2020

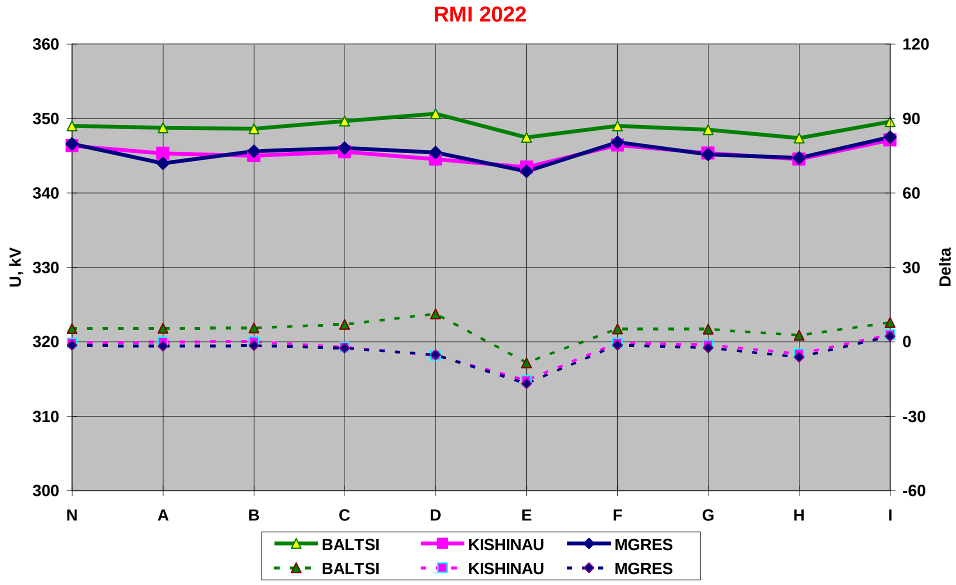

Figure 4.3 Voltages and angles in transmission grid nodes, with N-1 elements in operation, for calculation model for year 2022

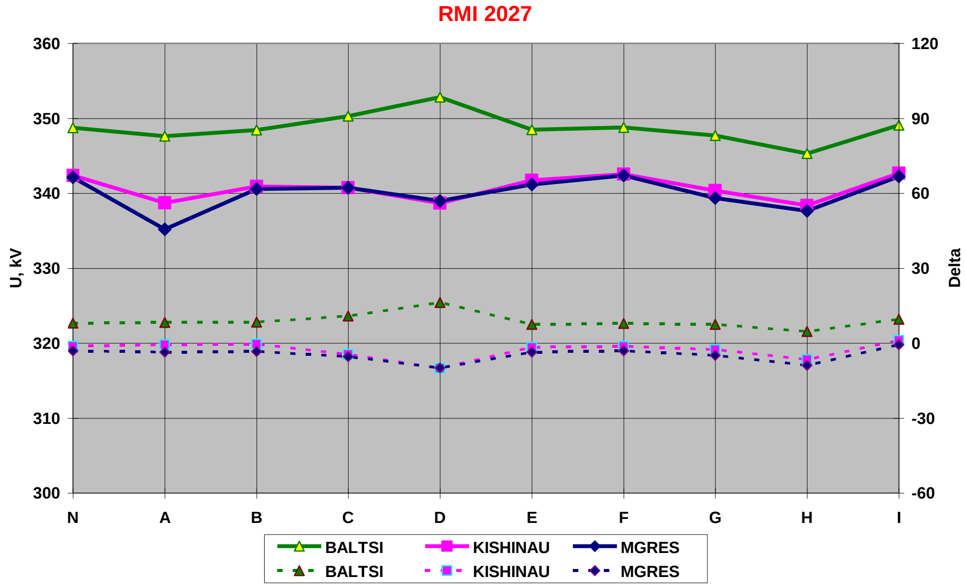

Figure 4.4 Voltages and angles in transmission grid nodes, with N-1 elements in operation, for calculation model for year 2027

Table 4.5 Voltages and angles in transmission grid nodes, with N-2 elements in operation, for calculation model for year 2020

Scenario			A+H		C+E		D+E		H+I	
Node #	Node name	Unom, kV	U, kV	Delta	U, kV	Delta	U, kV	Delta	U, kV	Delta
34061	KISHINAU	330	339,71	-5,37	321,97	-44,46	310,60	-51,42	340,62	-4,34
30100	MGRES	330	342,77	-5,29	323,60	-44,21	311,93	-49,94	344,15	-4,34
32049	BALTSI	330	344,58	1,94	343,55	-29,14	345,13	-24,38	345,12	2,69
36046	VULKANES	400	429,74	-10,42	380,22	-45,17	366,29	-51,31	407,01	-1,28
32028	FLORESHT	110	112,10	-3,75	111,72	-34,75	110,00	-34,37	112,32	-2,91

Table 4.6 Voltages and angles in transmission grid nodes, with N-2 elements in operation, for calculation model for year 2022

Scenario			A+H		C+E		D+E		H+I	
Node #	Node name	Unom, kV	U, kV	Delta	U, kV	Delta	U, kV	Delta	U, kV	Delta
34061	KISHINAU	330	343,17	-4,53	341,41	-17,97	339,78	-22,12	344,49	-4,73
30100	MGRES	330	341,67	-6,57	341,10	-18,52	339,41	-21,88	344,61	-6,04
32049	BALTSI	330	346,83	2,69	348,74	-6,32	350,29	-1,75	347,37	2,65
36046	VULKANES	400	411,87	3,63	402,01	-13,71	400,54	-17,47	406,60	-0,23
32028	FLORESHT	110	114,85	-2,07	115,50	-10,29	115,50	-9,11	115,24	-2,00

Table 4.7 Voltages and angles in transmission grid nodes, with N-2 elements in operation, for calculation model for year 2027

Scenario			A+H		C+E		D+E		H+I	
Node #	Node name	Unom, kV	U, kV	Delta	U, kV	Delta	U, kV	Delta	U, kV	Delta
34061	KISHINAU	330	332,29	-6,25	339,73	-5,05	337,49	-10,62	334,92	-10,23
30100	MGRES	330	327,56	-9,59	339,53	-5,89	337,50	-10,46	333,48	-12,8
32049	BALTSI	330	342,97	4,85	350,20	10,38	352,72	15,78	343,11	2,18
36046	VULKANES	400	403,60	2,73	400,60	-0,50	398,78	-5,60	396,19	-6,68
32028	FLORESHT	110	111,99	-1,25	115,50	5,01	115,23	6,13	112,43	-4,13

4.5. Transient stability assessment of power system

In operational planning studies for power system of Republic of Moldova there have been performed the analysis of transient stability. Five three phase metallic short circuit scenarios have been considered, on bus burs and electric lines (Table 2.9).

The obtained results of transient process simulations of mentioned short-circuits are shown in Figures 4.5 -4.11.

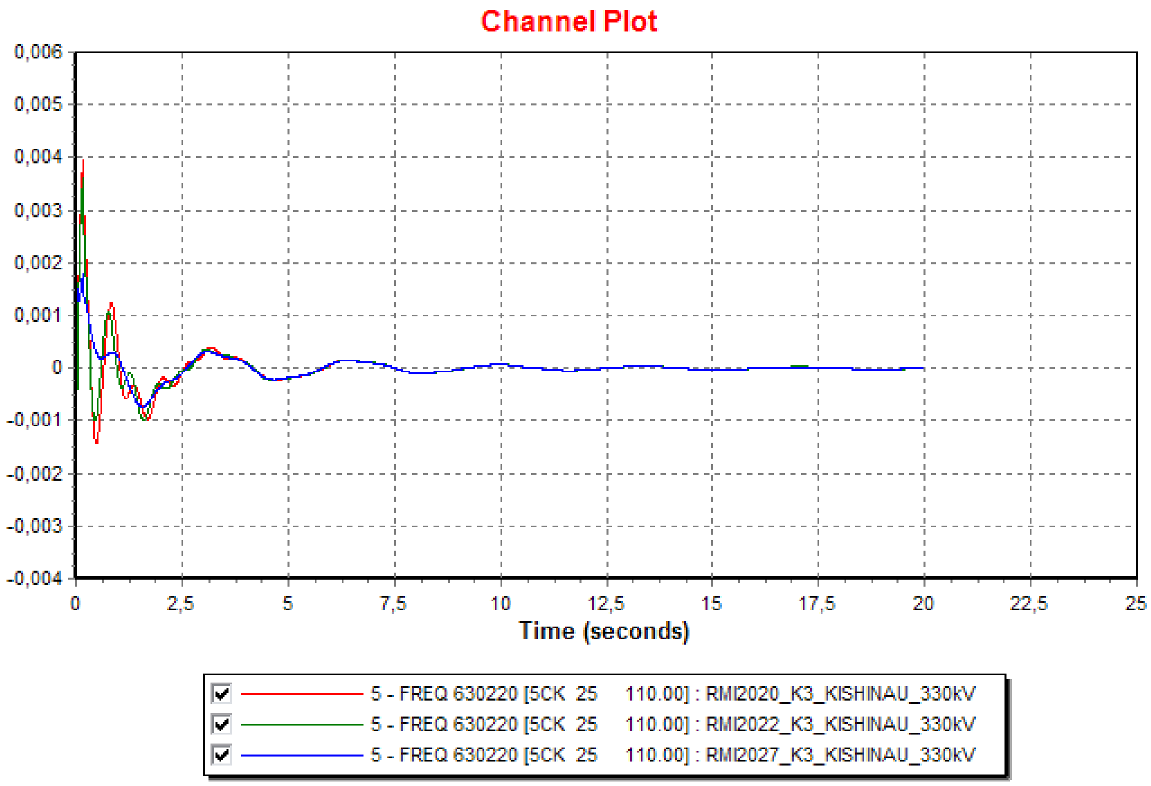

Figure 4.5 Power system frequency for characteristic frames

It can be seen that the frequency deviation does not exceed the value of 0.2 Hz and is being restored within 5 seconds.

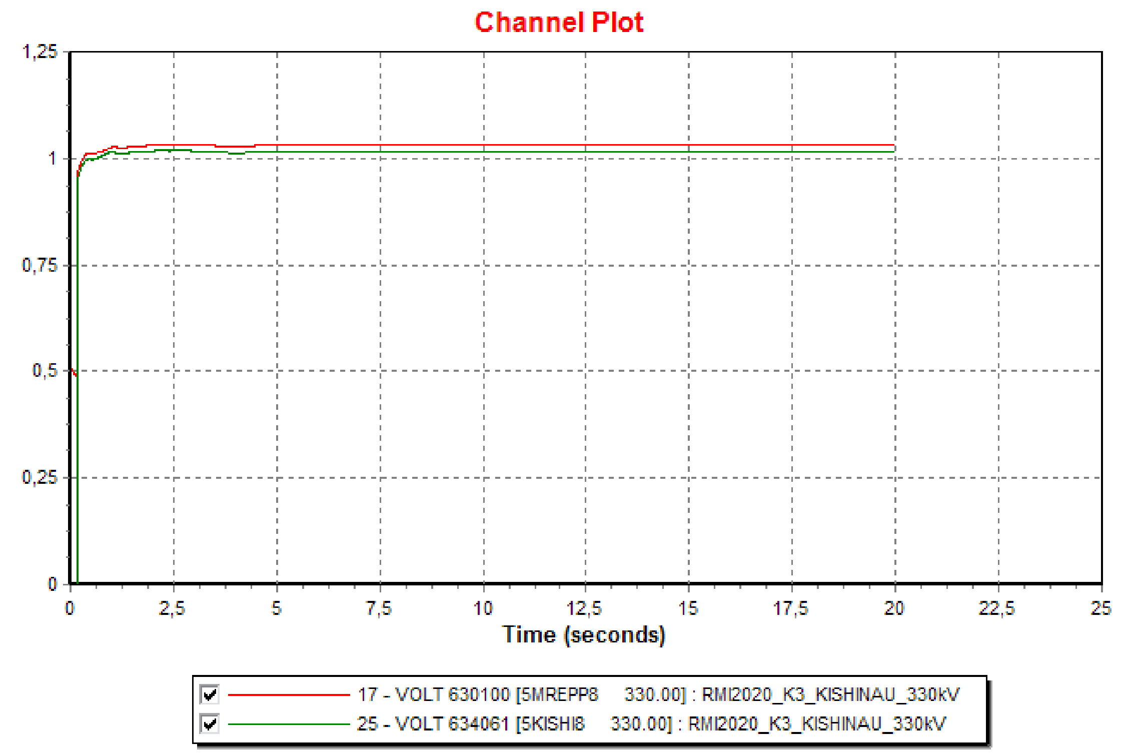

Figure 4.6 Voltages for reference scenario (year 2020)

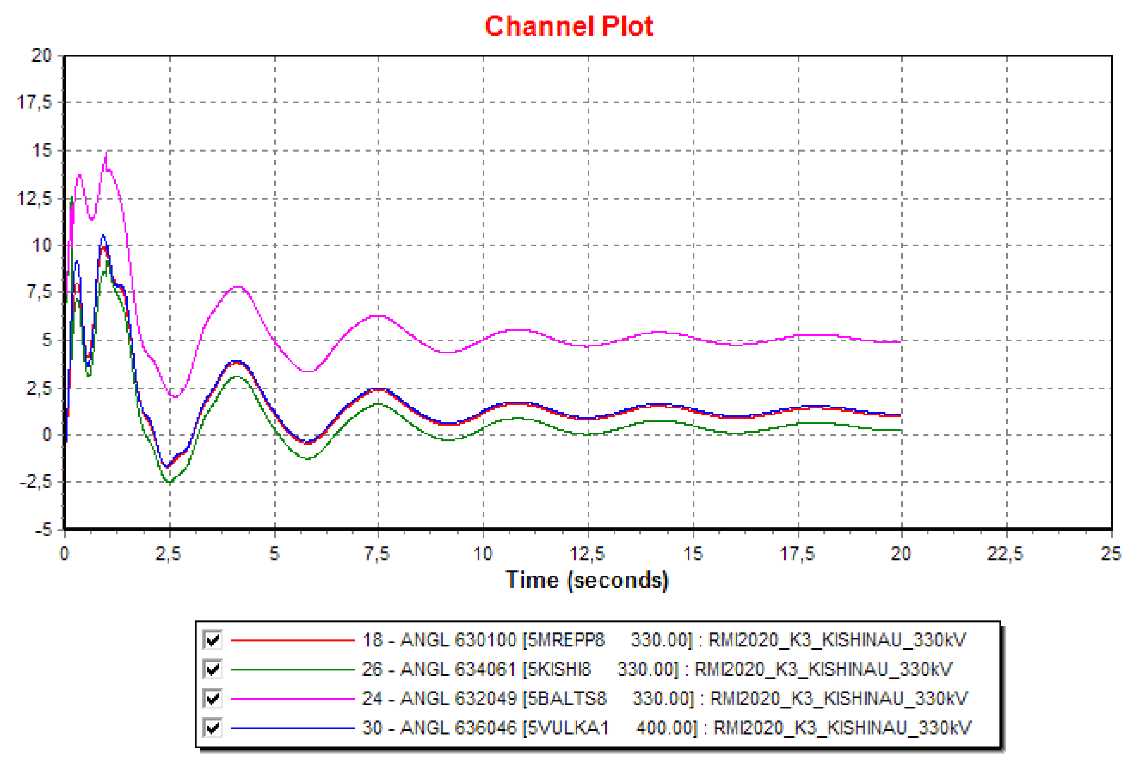

Figure 4.7 Angles for reference scenario (year 2020)

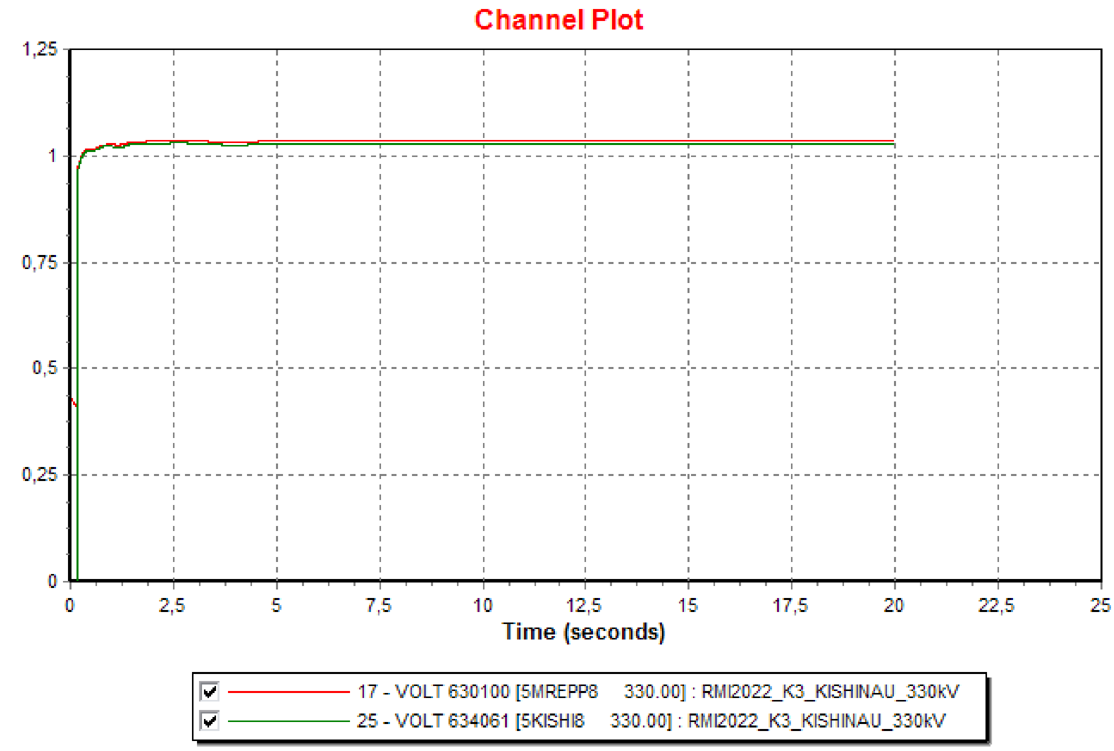

Figure 4.8 Voltages for reference scenario (year 2022)

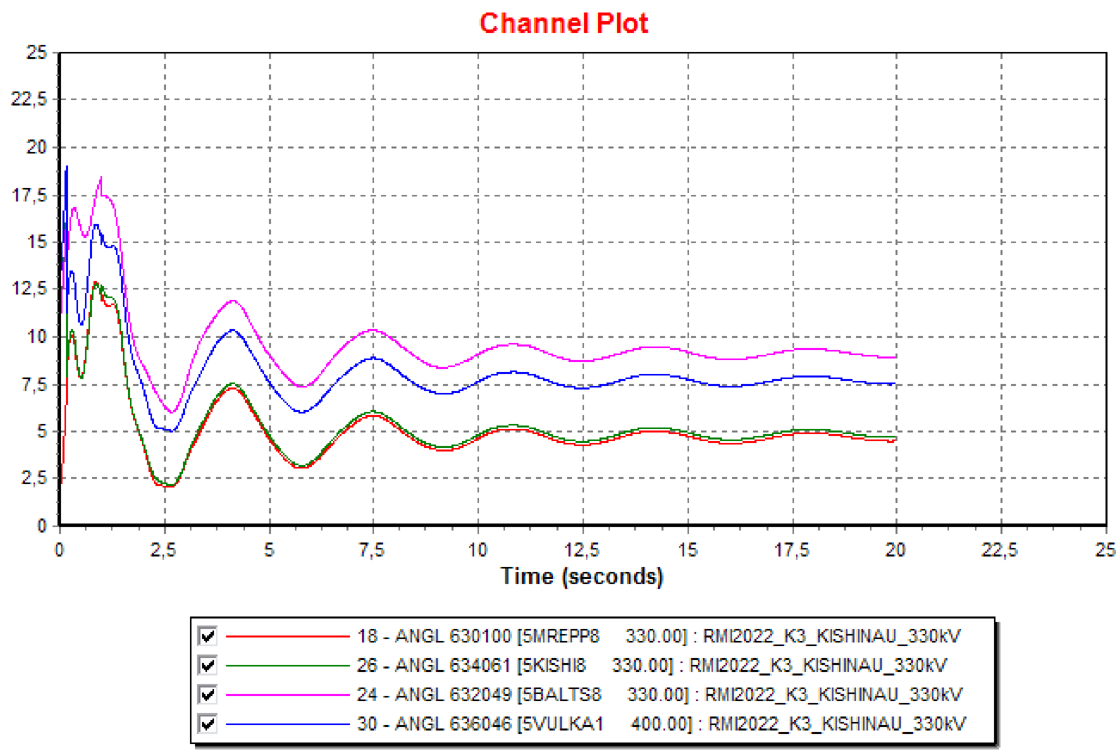

Figure 4.9 Angles for reference scenario (year 2022)

The results show that during short circuit the voltage in transmission grid nodes drop in a strict relationship with the distance from the short circuit location. After disconnection of the short circuit and automatic re-closure of disconnected element, voltages are being restored to the values close to the ones prior the short circuit event. It should be noted that no case has not been identified in which voltage stabilization process takes more than 0.02 … 0.03 seconds.

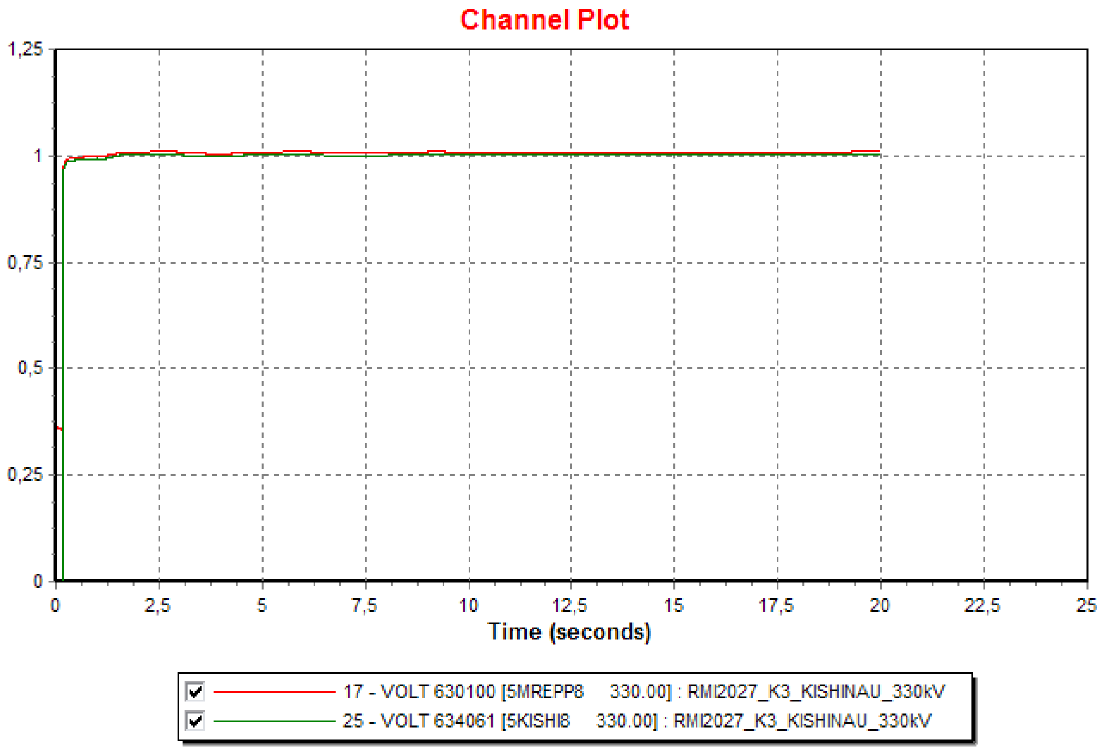

Figure 4.10 Voltages for reference scenario (year 2027)

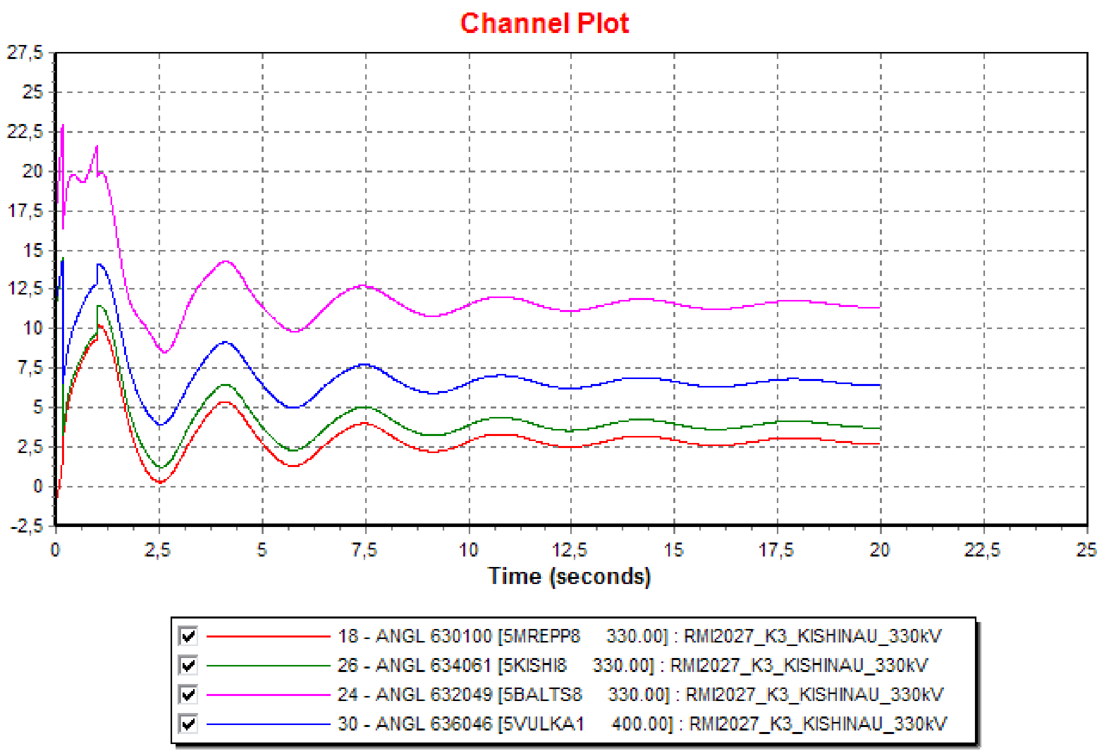

Figure 4.11 Angles for reference scenario (year 2027)

It can be observed that during short circuit the angles jump doesn't exceed 25 degrees. After short circuit disconnection and automatic re-closure of disconnected element (0.06 ... 0.09 s), the angles are stabilized at values corresponding to the permanent regime.

5. ESTIMATION OF INVESTMENTS

5.1. Development of electricity transmission grid structure

5.1.1. Existing policy regarding investments

Investment policy of SE Moldelectrica is based on identification of yearly investments needs which are assembled into a Yearly Investment Plan.

The main accent is on making the investments that are strictly necessary, that are driven from operational needs and principles of ensuring transmission grid equipment maintenance. This is mainly due to available own financial means that are regulated and have a significant impact on electricity transmission service tariff as well as on end consumer tariff.

Allocated financial means for investments have been proven insufficient for remedying the existing technical situation of the equipment that is on company balance sheet, information that is shown in chapter 2.1. It should be noted that in the mentioned chapter it is not shown the information regarding the current situation of buildings and constructions, as well as the current technical state of transportation means and machinery, but which have been analyzed and for which the investment needs have been identified.

This discrepancy is the result of insufficient allocated financial means for investments, which depends on the tariff for electricity transmission and dispatching service, as well as of the technical possibilities of making the investment that depends on the possibility of disconnecting the equipment for a long period and on the market availability for providing sufficient subcontractors for implementing all yearly planned investments.

More than that, in the context of the clear established major priority of Republic of Moldova to interconnect its power system with power system of ENTSO-E, allocation for investments in modernization, reconstruction and refurbishments of power system electric equipment, as well as reconstruction at scale of 35-400 kV OHL, became of a utmost importance.

Another aspect that should be mentioned is implementation of the „SE Moldelectrica Transmission Network Rehabilitation Project" that is financed by *European Bank for Reconstruction and Development (20 mln. USD),* European Investment Bank (17 mln. USD) and Neighborhood Investment Facility (8 mln. EURO grant). The projects have an estimated implementation timeframe of 4 years and is specifically intended for replacement of old equipment and reconstruction/construction of 110 kV OHL and 110kV substations.

5.1.2. Development perspectives of electricity transmission grid

SE Moldelectrica's yearly investment programs are regulated according to Regulation regarding planning, approval and making investments [60].

Company's yearly investment plans have to be developed by taking into consideration the Ten-year development plan, which implies identification of investment programs and projects that are to be reflected in SE Moldelectrica's yearly investment programs.

The investment projects will be analyzed and grouped in the following categories:

1. *Category A:* Investments in new networks and new production capacities;
2. *Category B:* Investments in existing networks and production capacities (*reconstruction, modernization, retrofit, major capital repairs of network and production installations*);
3. *Category C:* Investments in transportation means, vehicles, mechanical machinery;
4. *Category D:* Investments in measuring equipment, control and diagnosis devices including related to the electrical grid;
5. *Category E:* Investments in buildings and constructions, including related to electrical grid;
6. *Category F:* Investments in computing and remote communication;
7. *Category G:* Investments in intangible assets (software, licenses, etc.);
8. *Category H:* Other investments related to licensed activity.

Table 5.1 List of investment projects for the 2018-2027 period

A	**Investments in new networks and new production capacities**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	600 MW BtB station at Vulcăneşti			■	■	■					
2	OHL 400 kV Vulcăneşti – Chişinău				■	■					
3	New 400 kV switchyard and reconstruction of the 330 kV switchyard at SS Chisinau 330 kV			■	■	■					
4	OHL 400 kV Bălţi - Suceava									■	■
5	OHL 35-110 kV (Şoldăneşti-Ignăţei)		■								
6	Reconstruction of SS 110 kV Otaci and Cauşeni and addition of a new 110 kV bay		■	■							
7	Reconstruction of 110 kV switchyard and addition of a new 110 kV bay at SS (SS Goteşti and Edineţ)	■	■								
8	New power transformer and bay at SS Ialoveni 110 kV, including protection circuits		■								
B	**Investments in existing networks and production capacities**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	Reconstruction of OHL 400 kV Isaccea - Vulcănesti with installation of OPGW			■							
2	Reconstruction of 330-400 kV OHL	■	■	■	■	■	■	■	■	■	■
3	Reconstruction of 35-110 kV OHL	■	■	■	■	■	■	■	■	■	■
4	Construction of 400 kV switchyard and reconstruction of 330 kV switchyard at SS Bălţi 330 kV								■	■	■
5	Reconstruction of 400kV switchyard at SS Vulcăneşti 400 kV		■	■							
6	Reconstruction of 35 kV switchyard at SS Chişinău 330 kV		■								
7	Replacements of 400 kV shunt reactors	■									
8	Replacement of 35 kV booster transformers 63MVA	■									
9	Replacement of 35-110 kV power transformers	■	■	■	■	■	■	■	■	■	■
10	Replacement of 110 kV breakers of type BMT and MMO with SF6 breakers	■	■								
11	Replacements of 110 kV breakers of type У, МКП, ВВН and ВВШ with SF6 breakers	■	■	■	■	■	■	■	■	■	■
12	Replacement of 330 kV current and voltage transformers	■		■		■		■		■	
13	110 kV current and voltage measurement transformers	■	■	■	■	■	■	■	■	■	■
14	Replacement of 110 kV disconnectors with remotely controlled disconnectors	■	■	■	■	■	■	■	■	■	■
15	Reconstruction of 10 kV switchyard	■	■	■	■	■	■	■	■	■	■
16	Modernization of 110 kV switchyard by replacing automatic disconnectors and earthing switches with SF6 breakers			■	■	■	■	■	■	■	■
17	Modernization of 35 kV switchyard by replacing automatic disconnectors and earthing switches with breakers, including line, bus bar and bypass breakers					■	■	■	■	■	■
18	Relay protection and automation modernization of 400 kV AT and 400 kV OHL			■	■						
19	Relay protection and automation modernization of 330 kV AT	■	■	■	■	■	■				
20	Relay protection and automation modernization of 110kV OHL and 110-330kV bus bars	■	■	■	■	■	■	■	■	■	■
21	Relay protection and automation modernization of 35-110 kV power transformers	■	■	■	■	■	■	■	■	■	■
22	Replacements of SS auxiliary supply panels and batteries	■		■		■		■		■	

Table 5.1 List of investment projects for the 2018-2027 period

C	**Investments in transportation means, vehicles, mechanical machinery**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	Transport means and specialized machinery										
2	Transport means for operative repair teams										
3	Vehicles for transportation to substations										
D	**Investments in measuring equipment, control and diagnosis devices including related to the electrical grid**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	Measuring equipment, including electricity meters and reconstruction of electricity metering systems (10 kV current and voltage transformers)										
2	Installations for diagnosis and control of equipment										
E	**Investments in buildings and constructions, including related to electrical grid**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	Capital improvements/repairs of buildings										
2	Roof reconstruction by replacing slate sheets with metal tiles										
3	35-330 kV switchyard reconstruction by replacing the reinforced concrete constructions										
4	Energy efficiency measures related to buildings										
F	**Investments in computing and remote communication**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	RTU based implementation of 10 kV feeders remote control and data acquisition										
2	Implementation of substations remote control and data acquisition for integration in SCADA system										
3	Lines reconstruction by replacement of cuprum wires with fiber optic.										
4	Reserve supply sources, accessories for systems interconnection, etc.										
5	Computing equipment										
G	**Investments in intangible assets**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	Studies, software, licenses for SCADA, software for automated electricity measurement system and production activity										
H	**Other investments related to licensed activity**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**
1	Security systems and critical infrastructures										
2	Measures for interconnection of power systems of Moldova and Ukraine to power system of ENTSO-E CE										

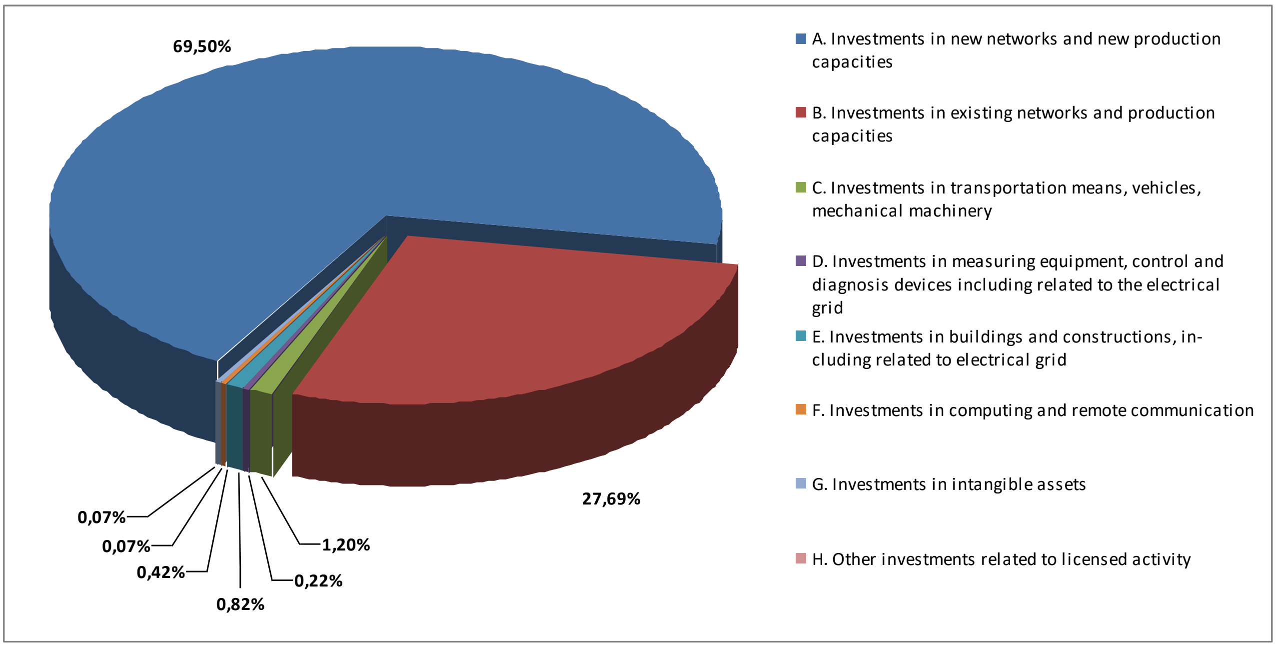

Figure 5.1 Investments structure for 2018-2027 period

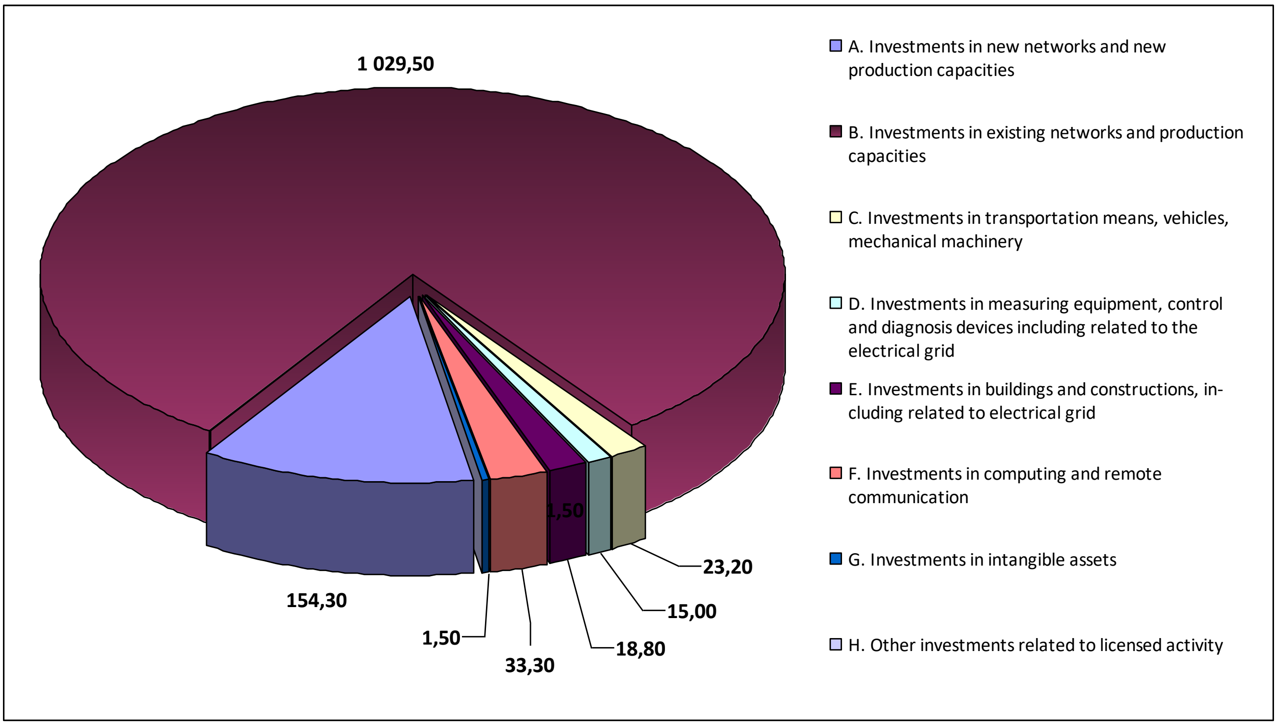

Figure 5.2 Investments distribution for 2018-2020 period, mln. Lei

Table 5.2 Investment projects list for 2018-2020 period, Category A

#	Investment	TSO detailed investments for the following 3 years			2018		2019		2020		Arguments and priority investments objects
		Total quant.	Total, mln. lei		Source, mln. lei		Source, mln. lei		Source, mln. lei		
			PIN*	PICR**	PIN	PICR	PIN	PICR	PIN	PICR	
A	**Investments in new networks and new production capacities**	**154,30**	**18,30**	**136,00**	**3,00**	**-**	**15,30**	**78,50**	**-**	**57,50**	
1	Construction of 35-110 kV OHL (Şoldăneşti-Ignăţei), km	22	-	18,50				18,50			Implementation of "Transmission network rehabilitation" project, Package D
2	Reconstruction of 110 kV SS Otaci and Cauşeni with addition of new 110 kV bays, SS	2	-	117,50				60,00		57,50	Implementation of "Transmission network rehabilitation" project, Package C
3	Reconstruction of 110 kV switchyard with addition of new 110 kV bays (SS Goteşti and SS Edineţ), bays	2	6,00	-	3,00		3,00				Reconstruction of SS Goteşti 110 kV, required in order to ensure the full functionality of OHL 110 kV Goteşti-Fălciu, and reconstruction of SS Edineţ 110 kV, required for ensuring the direct connection to substation of T-connection to SS Burlăneşti, currently from OHL 110 kV Edineţ-Cuconeşti
4	A second power transformer and connection bay at SS Ialoveni 110 kV, including relay protection circuits, units	1	12,30	-			12,30				Transmission capacity and reliability increase of SS Ialoveni 110 kV

* PIN – New investment projects,
** PICR – Ongoing investment projects.

Table 5.3 Investment projects list for 2018-2020 period, Category B

#	Investment	TSO detailed investments for the following 3 years			2018		2019		2020		Arguments and priority investments objects
		Total quant.	Total, mln. lei		Source, mln. lei		Source, mln. lei		Source, mln. lei		
			PIN	PICR	PIN	PICR	PIN	PICR	PIN	PICR	
B	**Investments in existing networks and production capacities**	**1029,50**	**310,20**	**719,30**	**112,70**	**386,75**	**94,70**	**280,75**	**102,80**	**51,80**	
1	Reconstruction of OHL 400 kV Isaccea - Vulcănesti with installation of OPGW, km	37	-	30,80						30,80	With construction of BtB station at Vulcanesti, it is necessary to ensure data transmission between SCADA systems of Romania and Moldova TSOs by establishment of a data channel that can be implemented by replacing the existing protection wire with an OPGW wire.
2	Reconstruction of 330-400 kV OHL, km	6	7,80	-	2,50		2,60		2,70		Correcting the 330-400 kV OHL lines dimensions that have been identified during periodic inspections and reconstruction of OHL in order to comply with the new requirements (NAIE 7th edition), that require replacement or addition of towers in order to decrease the span.
3	Reconstruction of 35-110 kV OHL, km	267	144,90	94,50	49,50	44,50	39,60	50,00	55,80		Implementation of “Transmission network rehabilitation” project, that includes reconstruction of 110 kV OHL with installation of OPGW, with a total length of 106 km (OHL 110 kV Drochia-Şuri-Donduşeni, OHL 110 kV Chişinău 330 kV-Hînceşti-Cneazev-ca). Priority investments from own funds of 161 km (OHL 110 kV Bălţi 330 kV-Biliceni 29 km, OHL 110 kV Donduşeni-Lencăuţi with OPGW 26 km, OHL 110 kV Donduşeni-Edineţ with OPGW 27 km, OHL 110 kV Cneazevca-Leova with OPGW 44 km, OHL 110 kV Chişinău 330 kV-Sîngera-Anenii Noi with OPGW 33 km, strengthening the OHL 110 kV Anenii Noi-Căuşeni 2 km).
4	Reconstruction of 400kV switchyard at SS Vulcăneşti 400 kV, bays	2	-	51,00				30,00		21,00	Implementation of “Transmission network rehabilitation” project, Package C
5	Reconstruction of 35 kV switchyard at SS Chişinău 330 kV, bays	11	-	25,50				25,50			Implementation of “Transmission network rehabilitation” project, Package C
6	Replacements of 400 kV shunt reactors, pieces	3	-	47,50		47,50					Implementation of “Transmission network rehabilitation” project, Package A2
7	Replacement of 35 kV booster transformers 63MVA at SS Chişinău 330 kV, pieces	2	-	23,50		23,50					Implementation of “Transmission network rehabilitation” project, Package A1
8	Replacement of 35-110 kV power transformers, pieces	10	-	102,50		71,75		30,75			Implementation of “Transmission network rehabilitation” project, Package A1
9	Replacement of 110 kV breakers of type BMT and MMO with SF6 breakers, including modernization of control and automation devices, pieces	50	2,70	29,00	2,0	19,00	0,70	10,00			Implementation of “Transmission network rehabilitation” project, Package B, including modernization of control and automation devices from own funds.
10	Replacements of 110 kV breakers of type Y, МКП, ВВН and ВВШ with SF6 breakers, pieces	119	7,60	19,50	1,50	10,00	1,50	9,50	4,60		Implementation of “Transmission network rehabilitation” project, Package B

Table 5.3 Investment projects list for 2018-2020 period, Category B

#	Investment	TSO detailed investments for the following 3 years			2018		2019		2020		Arguments and priority investments objects
		Total quant.	Total, mln. lei		Source, mln. lei		Source, mln. lei		Source, mln. lei		
			PIN	PICR	PIN	PICR	PIN	PICR	PIN	PICR	
B	**Investments in existing networks and production capacities**	**1029,50**	**310,20**	**719,30**	**112,70**	**386,75**	**94,70**	**280,75**	**102,80**	**51,80**	
11	Replacement of 330 kV current and voltage transformers, pieces	9	4,50	-	1,50		1,50		1,50		Replacement of 330 kV current transformers of AT-4 type for which is not possible to foresee the rapidly deterioration of characteristics (at SS Bălţi 330 kV bay 330Î1S, at SS Chişinău 330 kV bays 330Î24 and 330Î15)
12	110 kV current and voltage measurement transformers, pieces	123	0,00	22,50		12,50		10,00			Implementation of "Transmission network rehabilitation" project, Package B
13	Replacement of 110 kV disconnectors with remotely controlled disconnectors, pieces	177	0,00	32,00		17,00		15,00			Implementation of "Transmission network rehabilitation" project, Package B
14	Reconstruction of 10 kV switchyard, pieces	17	24,30	241,00	8,00	141,00	8,10	100,00	8,20		Implementation of "Transmission network rehabilitation" project, Package E, including reconstruction of 10 kV switchyard at SS Ialoveni 110 kV
15	Modernization of 110 kV switchyard by replacing automatic disconnectors and earthing switches with SF6 breakers, sets	2	5,40	-	1,70		1,80		1,90		Replacement of automated disconectors and earthing switches from transformer bays during implementation of "Transmission network rehabilitation" project, Package A1, especially at SS Bălţi Centrală 110 kV
16	Relay protection and automation modernization of 400 kV AT and 400 kV OHL, sets	5	9,00	-	1,80				7,20		Investments related to implementation of "Transmission network rehabilitation" project, Package C
17	Relay protection and automation modernization of 110kV OHL and 110-330kV bus bars, sets	65	92,30	-	40,30		35,00		17,00		Investments related to implementation of "Transmission network rehabilitation" project, Package B, especially 110 kV breakers at SS Vulcăneşti 400 kV, SS Chişinău 330 kV, SS Străşeni 330 kV
18	Relay protection and automation modernization of 35-110 kV power transformers, sets	9	7,20	-	2,40		2,40		2,40		Investments related to implementation of "Transmission network rehabilitation" project, Package A1, at SS Bălţi Centrală 110 kV, SS Goteşti 110 kV, SS Călăraşi 110 kV, SS Vatra 110 kV, SS Cioropcani 110 kV, SS Colicauti 110 kV, and SS Beleaveneti 110 KV.
19	Replacements of substations auxiliary supply panels and batteries, sets	3	4,50	-	1,50		1,50		1,50		Replacement of moral and physical depreciated auxiliary supply panels and batteries for which have been proven unacceptable characteristics, especially at SS Străşeni 330 kV and Floreşti 110 kV

Table 5.4 Investment projects list for 2018-2020 period, Category C, D, and E

#	Investment	TSO detailed investments for the following 3 years			2018		2019		2020		Arguments and priority investments objects
		Total quant.	Total, mln. lei		Source, mln. lei		Source, mln. lei		Source, mln. lei		
			PIN	PICR	PIN	PICR	PIN	PICR	PIN	PICR	
C	**Investments in transportation means, vehicles, mechanical machinery**	**23,20**	**23,20**		**7,60**		**7,70**		**7,90**		
1	Transport means and specialized machinery, pieces	6	12,15	-	4,00		4,05		4,10		Acquisition of specialized machinery (specialized vehicles) to replace the moral and physical depreciated ones that have been put out of operation after technical inspection or due to prescriptions from authorized organizations.
2	Transport means for operative repair teams, pieces	12	8,55	-	2,80		2,85		2,90		Continuation of the investment campaign for modernization of vehicles for operative maintenance and repair teams in order to minimize the transportation time for remediation of defects and other interventions. Replacement of moral and physical depreciated transportation assets that as well have a poor fuel efficiency.
3	Vehicles for transportation to substations, pieces	9	2,50	-	0,80		0,80		0,90		
D	**Investments in measuring equipment, control and diagnosis devices including related to the electrical grid**	**13,50**	**13,50**		**3,50**		**4,50**		**5,50**		
1	Measuring equipment, including electricity meters and reconstruction of electricity metering systems (10 kV current and voltage transformers)	-	13,50	-	4,00		4,50		5,00		Initiation of investment campaign for fulfilling the minimum technical requirements and regulation framework for commercial metering system of electricity, replacement of current and voltage transformers that show unacceptable technical and metrological characteristics.
2	Installations for diagnosis and control of equipment, pieces	-	1,50	-	0,50		0,50		0,50		In cases with significant share of moral and physical depreciated equipment (at this point being 65%), investments in modern diagnostics and control equipment, show to be a priority.
E	**Investments in buildings and constructions, including related to electrical grid**	**18,80**	**18,80**		**3,50**		**3,60**		**11,70**		
1	Capital improvements/repairs of buildings, pieces	3	3,15	-	1,00		1,05		1,10		Capital repairs and reconstruction of premises of administrative building and dispatch posts are a result of physical condition and optimization of those premises
2	Roof reconstruction by replacing slate sheets with metal tiles, pieces	6	6,15	-	2,00		2,05		2,10		Unacceptable physical condition, often leakages, including exclusion of slate sheets usage, measures related to environment protection at national level
3	35-330 kV switchyard reconstruction by replacing the reinforced concrete constructions, substations	1	8,00	-					8,00		Investments in reconstruction of civil constructions of 35-330 kV switchyards are the results of poor condition of concrete portals, especially there is the need for finalization of reconstruction of 110 kV switchyard at SS SE Bălţi 330 kV by replacing the concrete structures of 110 kV bus bars (entrance portals and bypass bus bar system have already been reconstructed)
4	Energy efficiency measures related to buildings	-	1,50	-	0,50		0,50		0,50		Contribution and fulfilment of national energy efficiency programs, including measures for decreasing of building maintenance costs

Table 5.5 Investment projects list for 2018-2020 period, Category F, G, and H

#	Investment	TSO detailed investments for the following 3 years			2018		2019		2020		Arguments and priority investments objects
		Total quant.	Total, mln. lei		Source, mln. lei		Source, mln. lei		Source, mln. lei		
			PIN	PICR	PIN	PICR	PIN	PICR	PIN	PICR	
F	**Investments in computing and remote communication**	**33,30**	**33,30**		**8,60**		**10,50**		**14,20**		
1	RTU based implementation of 10 kV feeders remote control and data acquisition	15	3,70	-	1,00		1,20		1,50		Investments related to Energy II Project, component A3, during which 28 TSO substation and 4 electricity sources have been equipped with remote control and data acquisition systems, except the 10 kV feeders that was not in the scope of the project and are not included in SCADA. TSO has already modernized 5 substations and there is the need to continue with initiated investment project.
2	Implementation of substations remote control and data acquisition for integration in SCADA system	28	8,80	-	5,00		1,70		2,10		For ensuring the remote control and data acquisition throw-out the whole power system with integration in existing SCADA system, there are 28 substation left to undergo the investments in this regard (from 183 substations owned by TSO) and are planned for the following 3 years.
3	Lines reconstruction by replacement of cuprum wires with fiber optic.	125	19,00	-	2,00		7,00		10,00		Reconstruction by replacement of cuprum wires with fiber optic, for line with exceeded life time, especially for ensuring reliability and security of data transmission for SCADA, between national dispatch center – SOD Vatra – SS Straseni 330 kV.
4	Reserve supply sources, accessories for systems interconnection, etc.	-	0,90	-	0,30		0,30		0,30		Investments related to remote control and data acquisition of substations and reconstruction of OHL by installation of OPGW.
5	Computing equipment	-	0,90	-	0,30		0,30		0,30		Investments related to modernization of computing equipment for ensuring the compatibility of programs and other software, minimum requirements, including replacement of moral and physical depreciated equipment.
G	**Investments in intangible assets**	**1,50**	**1,50**		**0,50**		**0,50**		**0,50**		
1	Studies, software, licenses for SCADA, software for automated electricity measurement system and production activity	-	1,50	-	0,50		0,50		0,50		Investments for studies, software, programs, licenses, especially for SCADA, that aims for optimization of production activity and ensuring the functionality in cases there is need for modernization or increasing the capabilities and/or the capacity.
H	**Other investments related to licensed activity**	**1,50**	**1,50**		**0,50**		**0,50**		**0,50**		
1	Security systems and critical infrastructures	-	1,50	-	0,50		0,50		0,50		Investments in security measures and critical infrastructure, including cybersecurity. As a priority is reconstruction of video surveillance system at SS Vulcăneşti 400 kV.

Total yearly investments values for perilous 2018-2020 are shown in Figure 5.3.

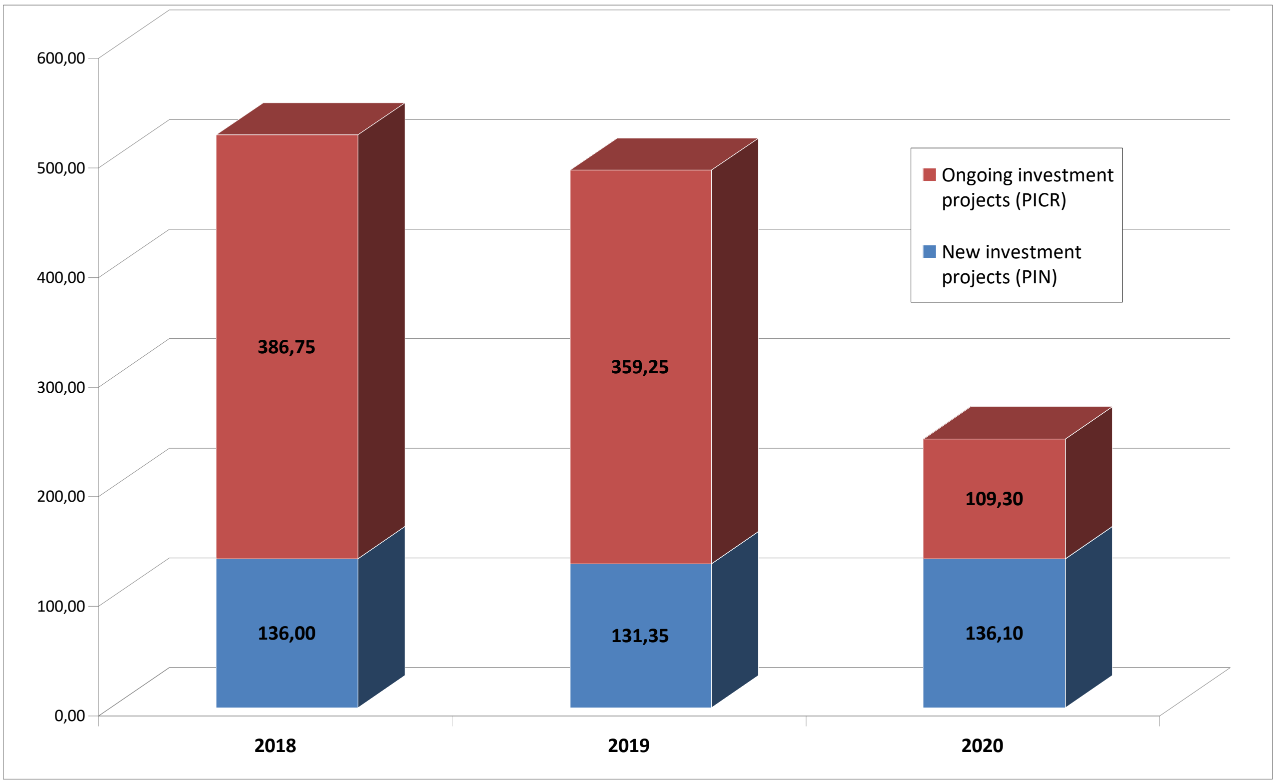

Figure 5.3 Yearly Investments for transmission grid development for the period 2018-2020, mln. Lei

Figures 5.4 and 5.5 shows the information regarding the distribution of financial means (in absolute units and percentages) for priority development directions of TSO for the period 2018-2020.

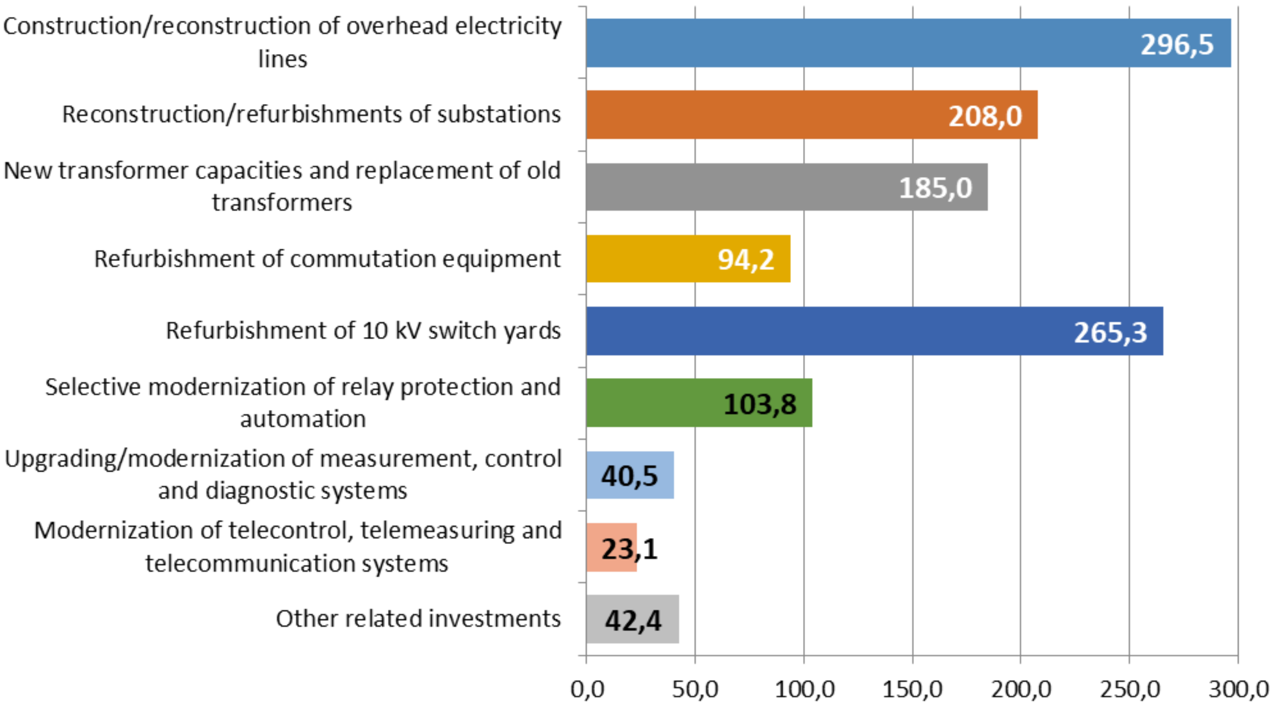

Figure 5.4 Distribution of investments for TSO priority development directions for the period 2018 – 2020, mln. Lei

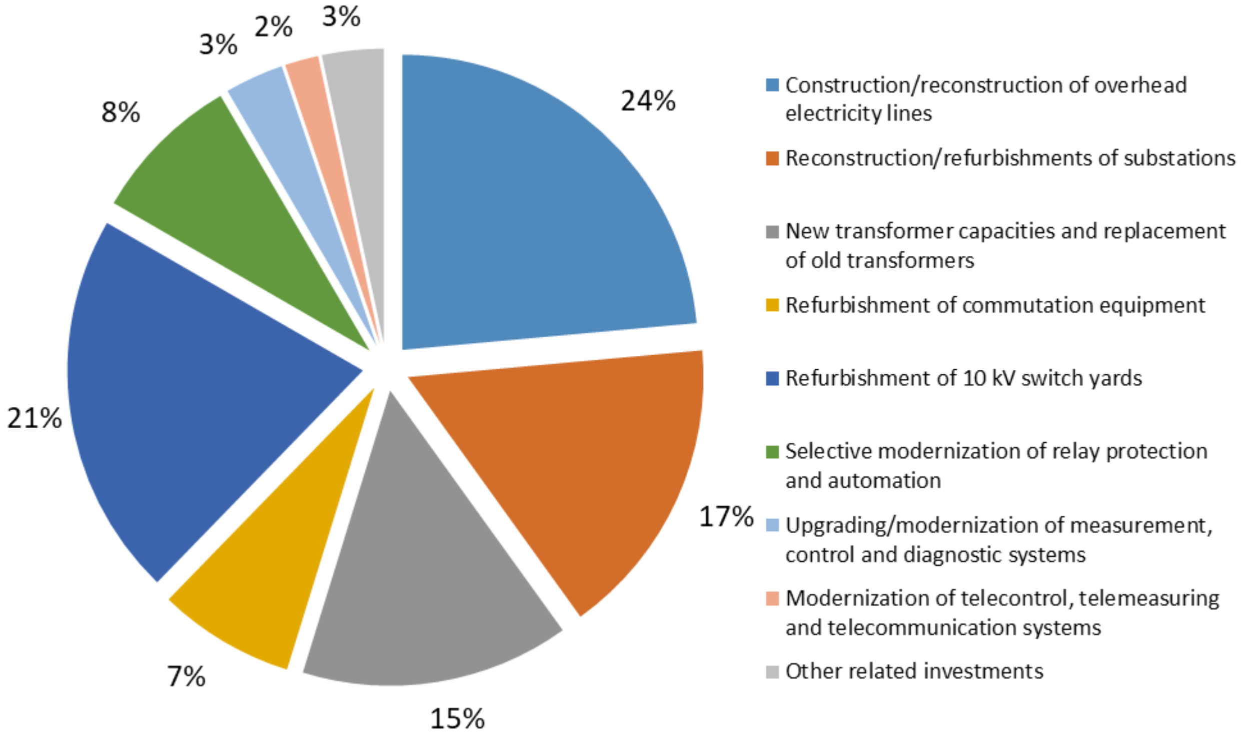

Figure 5.5 Distribution of investments for TSO priority development directions for the period 2018 – 2020

It is to be noted that investment for secondary circuits (relay protection, metering systems, remote control and data acquisition) are not limited only to target investments specifically for this directions but are also included in planned investments for refurbishments/modernization of substations as well as refurbishment of 10 kV switchyards.

5.2. Renewable electricity sources integration

Up till now, TSO has issued 28 permits for transmission grid connection of RES, for a total capacity of 959.66 MW, from which 75.32 MW are for solar (photovoltaic) power plants.

On the same time, it should be mentioned that the requests for grid connection of RES sum up to a value that exceeds the available grid capacity as per system as whole as well as per specific zones and currently it can be expected that when grid congestions are to be resolved, 10 more permits could be analyzed for a total capacity of 397.6 MW.

The most requested zones for grid connection of wind and solar power plants are: 100 kV transit Comrat – Baimaclia – Gotesti – Vulcanesti, region of Vulcanesti 400 kV substation and Stefan Vodă 110kV substation.

As such, in order to effectively utilize the available grid capacity, SE Moldelectrica should constantly monitor and update the steps performed and action taken by each party that has been approved for grid connection. As such steps are investments in ensuring the land availability and technical detailed design of the project that show concrete undertaken steps in order to implement the project. These measures of constantly monitoring of project implementation, either as a requirement from TSO or as incentive from the potential electricity producer, lead to:

- permit revision by decreasing the generation units installed capacity and as such for the whole power plant;

- canceling of the permits due to impossibility of construction of the plant;
- total power revision and connection points and issue of a new permit;
- Permit canceling due to lack of response and inactivity of the potential producers on TSO inquires.

Even though a significant amount of power has been approved for grid connection of RES, very few have finalized the projects, and only small scale projects have been implemented and put in operation, such as 1.1 MW of wind power (second-hand equipment) in the region of Bratuseni and 0.5 MW of solar power in the region of Ungheni.

During last years a decrease of requests for transmission grid connection of RES is noted. This fact doesn't allow for fulfilling the RES integration targets and can be explained by the following:

1. Maximum capacity of electricity transmission grid infrastructure that has been reached (issue of new permits cannot be done without increasing the capacity or strengthening of the grid);
2. Uncertainties regarding regulation framework on grid connection and functioning of RES as well as future provisions of grid codes;
3. Issues related to current transmission grid technical norms in relation with other documents;
4. Lack of a balancing mechanism in Republic of Moldova;
5. Lack of the possibility for zonal tariffs for electricity generated from RES.

Significant investments for construction of RES power plants, insufficiency of legislative framework regarding promotion and integration of RES, has a negative impact on the process of implementation of ambitious projects of usage of renewable sources.

Main obstacle in promoting RES integration is the lack of approves tariffs for RES electricity with a time frame of 10-15 years along with difficulties related to land acquisition and change of destination for construction needs.

Nevertheless, during year 2026 a total of 226 guarantees of origin have been issued, for a total amount of electricity generated from RES, of 17.8 GWh [59]. It should be mentioned the most significant amount comes from a biomass power plant with an installed capacity of 2.4 MW, owned by Î.M. "Sudzucker Moldova" S.A from Drochia. Electricity produced from biogas (78,7%) accounts for the biggest share of electricity produced from RES in year 2016, followed by wind (13,9%) and solar (7,4%) (Fig. 5.6).

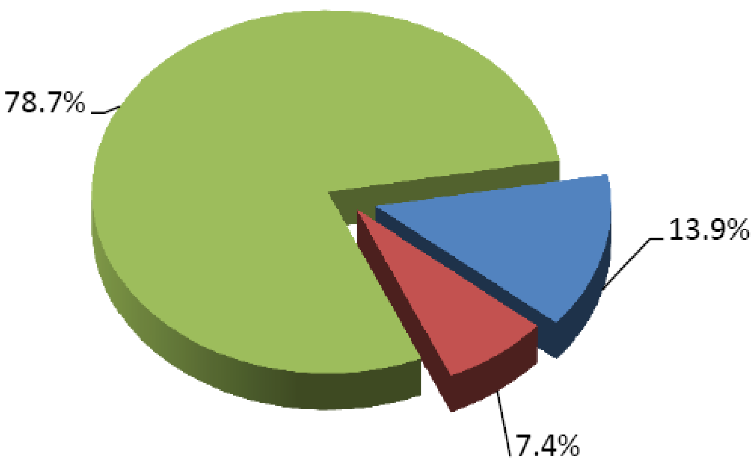

Figure 5.6 RES contribution, by type, from the total electricity produced

5.3. Interconnection with neighboring power systems

As per Energy strategy till 2030 [29], the target of diversification of electricity supply sources is envisaged to be achieved by accessing the EU internal electricity market and one of the solution is trough Back-to-Back stations at Vulcăneşti, Bălţi and Ungheni, that can also be used for power flows and voltage control, that will allow to minimize the power system loses.

On the same time there is the need for extension of interconnections with Romania in order to increase the operational security and increase the interface transmission capacity.

Interconnection with EU, beside increased security can offer as well better market prices as a result of increased competition that will lead to a better final electricity price for end consumers.

The congestion on Moldova – Ukraine interface limits the imports and transits of electricity. A second 330 kV circuit Bălţi – CHE Dnestrovsck might be an additional project for increasing the import capacity from power system of Ukraine. At this stage this project is not included in the 10-year development plan because Ukraine has not included it in its own development plan for period 2016 – 2025 and secondly, within a study performed by Technical University of Moldova [45], it hasn't been found significant improvements from the point of view of transmission grid operation.

Regarding the project of interconnection of power system of Ukraine and Moldova to the ENSTO-E power system, there is an optimistic scenario of achieving the interconnection within 6-8 years. A first step has been already taken by signing on 06.07.2017 of the Agreements regarding future interconnection of power system of Ukraine and Moldova to European continental power system. One of the possible required measures, included in this 10-year development plan, would be the construction of 400 kV OHL Bălţi – Suceava, estimated at 36.89 mln EURO on the territory of Republic of Moldova. Another envisaged project was Străşeni – Ungheni – Iaşi interconnection but was not included in this plan as due to the fact that SS Iasi has a voltage level of 220 kV, not all aspects related to connection on the Romanian part have been established at this point.

Taking into account the above mentioned as well as the priority set in Energy Strategy of Republic of Moldova till year 2030, regarding interconnection with neighboring systems, the development plan for the following 10 years would include investments projects shown in Table 5.6.

Table 5.6 Investment projects for interconnection with neighboring systems

	Investment project	Quant.	Total, mln. lei
1	600 MW BtB station at Vulcăneşti	1	4 514,4
2	Reconstruction of 400 kV switchyard in SS Vulcăneşti 400 kV	1	50,2
3	Construction of 400 kV switchyard and reconstruction of 330 kV switchyard in SS Chişinău 330 kV	1	351,1
4	Construction of 400 kV OHL Vulcăneşti - Chişinău, km	158	1128,6
5	Construction of 400 kV OHL Bălţi – Suceava (with extension of SS Bălţi 330 kV), km	52	750,0

Possible project that should be analyzed at the next revision of development plan are projects related to increasing the capacity of Ukraine – Moldova interface as well as increasing the transit capacity of internal transmission grid, for which some feasibility studies would be required.

5.4. Financing sources

The main sources of income for SE Moldelectrica is the regulated tariff for the transmission service which as well includes the service for power system dispatching.

TSO activity, being a natural monopoly, is a regulated one and according to the methodology for tariff calculation only services related to electricity transmission and dispatching are components that accounts for the income.

Financing structure for grid development includes the following:

- SE Moldelectrica own funds from base activity (mainly electricity transmission service);
- External sources that can be non-refundable (grants and possible European funds, others) and refundable from tariff (credits, others).

6. ENVIRONMENT PROTECTION AND SAFETY OF ELECTRICAL INSTALLATIONS

6.1. Environment impact of transmission grid infrastructure

Increase of electricity consumption is a long term trend that is present from the beginning of usage of this kind of energy type. Together with development of electricity sources there is the need for development of electricity transmission and distribution infrastructure, which will continue as long the traditional scheme of power system operation would be the optimal solution from the technical and economical point of view.

Environment impact of electricity transmission infrastructure can be seen from two points of view:

- Influence of electrical grid on surrounding environments;
- Influence of the surrounding environment of electrical grid.

Electricity transmission grids have a certain negative impact on the environment during the whole life time, starting from the construction (Table 6.1), continuing with service –maintenance period (Table 6.2), up till the final stage of decommissioning.

Table 6.1 Effects of different types of impacts as a result of electrical grid construction activity

Physical Impact
• opening of new access ways, soil scraping an excavation; • effects on flora (deforestation) and fauna (natural habitat fragmentation); • terrain usage for construction site, including storage; • Waste generation (metals, ceramic materials, glass, plastic materials, oil, concrete, debris, different packages, etc.).
Chemical Impact
• Usage of different chemical products (paint, solvent, reagents, etc.); • soil and water pollution by accidental oil and other chemical substances leakages from used equipment; • Emissions in atmosphere as by-products of gas burning (Cox. Sox, NOx, COV, powder) in heating and transportations means. • Emissions in atmosphere of sulfur hexafluoride emission due to equipment poor seals.
Sound Impact
• Noise generated during construction activity by construction equipment and transportation means.
Social – economic Impact
• Disruption of certain social activities including people reallocation.

Table 6.2 Effects of different types of impacts during service – maintenance stage of electrical grid

Physical Impact
• usage of terrain for OHL and substations; • systematic deforestation of vegetation; • effects on wild fauna habitats; • obstacles on birds' flyway; • potential burn and electrocution accidents; • sound and light manifestations of Corona; • disturbances of radio and television system; • influence on telecommunication installations or other electrical grids that are being crossed or that are relatively close; • Effects of electromagnetic field on living beings.
Visual Impact
• Landscape deterioration.
Sound Impact
• noise from transmission grid elements vibration during operation (wires) and especially power transformers and autotransformers; • Noise from Corona effect on high and very high voltage OHL.
Psychic Impact
• Fear of closing to electrical grid as well as of visual and sound effects caused by electrical grids.
Chemical Impact
• soil and water pollution by accidental oil and other substances leakages; • air pollution by emissions from heating installations, transportation means, batteries, sulfur hexafluoride; • Ozone and nitrogen oxides generation by Corona effect on high and very high voltages.
Mechanical Impact
• danger of possible collision with flying machines; • danger of falling near or on crossing of roads, railroads, river flows, buildings, etc.; • Danger of fire due to insulation damage or on accidental touch between wires and other objects or dry vegetation.

6.2. Legal requirements related to environment aspects

Main national regulations on environment protection, related to electricity transmission grid operation are:

- Law on accession of Republic of Moldova to the Convention on the Conservation of European Wildlife and Natural Habitats [30];
- Law on ratification of Agreement on the Conservation of African-Eurasian Migratory Water birds [31];
- Law on water [32];
- Law on harmful products and substances [33];
- Law on environment protection [34];
- ISO 140001:2006 standard „Environmental management” [35];
- Law on atmospheric air protection [36];
- Law on production and household waste [37];
- SE Moldelectrica regulation on ecological management in production activity [38];
- SE Moldelectrica regulation on waste verification in production and consumption activities [39];
- SE Moldelectrica regulation on environmental management on all implementation stage of Transmission network rehabilitation project [40];
- SE Moldelectrica regulation on environmental management [41];

According to legislation of Republic of Moldova, which is harmonized to the EU legislation, operation of electricity transmission grid is allowed only on basis of environmental authorization.

6.3. Measures for minimizing environmental impact of electricity transmission grid

Documents regarding execution of investments and maintenance works should contain a chapter dedicated for environment protection, aspects and measures for minimizing the environmental impact, and which will emphasize physically and by value. These measures are to be presented in a plan, Environmental management plan, that should include actions for minimizing environmental impact and for monitoring of environmental factors, as at the construction stage as well as at operation and maintenance stage. For each measure, an estimation of necessary funds is to be performed:

- Estimate for investments/maintenance should include costs for environment protection;
- Environmental management should be improved especially waste and wastewater management resulted from SE Moldelctrica activities;
- Special attention should be paid for improving oil management by performing oil accounting for each substation;
- Continuation of electromagnetic field parameters monitoring, especially on OHL located in polluted areas as well as noise measurement/monitoring at the substations boundaries;
- Improvements of environment management system and certification according to ISO 1400 standard requirements;
- For continuous improvement of SE Moldelectrica performances regarding environments aspects, all available possibilities should be used for information gathering and experience exchange with national and international partners, in the field of environment protection;
- A yearly environment report should be published by SE Moldelectrica for ensuring external communication in the field of environment protection.

6.4. Security of installations

Taking into account the international context of terrorist actions, the risk should be taken into account from the perspective of national security as a possible target for terrorist organizations.

Transmission grid installations that are operated by SE Moldelectrica can be targeted by terrorist actions as the effects that these actions can have start from electricity supply interruption of specific zones (isolated locations) and up to disturbance of the whole national power system with disastrous effects for all population and economy.

Taking into account the above mentioned, SE Moldelectrca has created within its organizational structure a dedicated department – „Critical infrastructure Department”, responsible for security and management of emergency situations with the task of electricity transmission grid installations protection as well as related informational systems, against different threats of terrorist or criminal type and organization of mitigation measures in cases of natural disasters, according to legal obligations:

- Decision on cyber security program of Republic of Moldova for years 2016-2020[20];
- Law on civil protection [43];
- Law on fire defense [44].

Main tasks of critical infrastructure departments for security and management of emergency situations:

- Ensuring a security level for electricity installations according to requirements and threats for national power system operation;
- Ensuring the defense capacity of SE Moldelectrica against disturbance factors of physical and informational nature;
- Organization and coordination of measures for emergency situation (civil protection and prevention, and fire extinguishing;
- Organization and deployment of measures for classified information protection;
- Implementation of specific projects for physical and informational security.

At this point physical protection of SE Moldelectrica installations are performed by guarding service provided by specialized companies.

Regarding informational protection, SE Moldelectrica applies the principle of knowledge need by granting access rights depending on occupied post and calcification of personnel. Access to local computer network of SE Moldelectrica is performed based on user and password that allows for access only to specific zones and application, necessary for performing in good conditions of the personnel activities.

CONCLUSIONS

SE Moldelectrica, as the Transmission System Operator, plans for electricity grid development by taking into account the current status and forecasted evolution of the electricity consumption, production fleet and electricity interchanges, and depending on the necessity, updates the then year development plan with the approval of National Energy Regulatory Agency of Republic of Moldova.

The development plan takes into account the requirements and priorities of Energy Strategy till year 2030, as well as the current normative framework. These are the determining references for identification of priority directions and forecast of evolution trends of the electricity sector.

At the base of development plan for 2018-2027 period are the power flow analysis of current and perspective configuration, by taking into account the electricity consumption evolution, production fleet and electricity interchanges with power systems of neighboring countries.

Currently there is a high degree of physical and moral deterioration of substation equipment (more than 60% have a service life of more than 30 years) and electric lines that accounts for electricity transmission grid of Republic of Moldova (67.5% are in service for more than 40 years).

The analysis of electricity transmission grid power flow computations for 2018-2027 period has shown that there are no overloads of electric lines.

Disconnection of generators from CERSM during winter and summer peak consumption regimes for the year 2018, doesn't lead to electricity transmission lines overload but results in low voltage levels in certain nodes of electricity transmission grid, especially in the southern zone of the national power system.

Planned integration of renewable sources (starting with year 2020) as well as the interconnection with power system of Romania by Back-to-Back stations (starting from year 2022), lead to improvements of voltage profile in electrical grid nodes, as during normal operating regimes as well as during N-1 and N-2 regimes.

Power system of Republic of Moldova, as part of IPS/UPS power system, is synchronously interconnected with power system of Ukraine by 7 x 330 kV OHL and 11 x 110 kV OHL and can operate with power system of Romania (part of continental Europe power system) by establishing consumption island on 1 x 400 kV OHL and 4 x 110 kV OHL.

Main identified investment projects for 2018-2027 period make an action plan that includes:

- 69,5% investments in building of new networks and production capacities;
- 27,7% investments in existing network and production capacities.

For 2018-2030 the proposed direction for investment allocation are:

- Construction/reconstruction of overhead electricity lines (24%);
- Refurbishment of 10 kV switch yards (21%);
- Reconstruction/refurbishments of substations (17%);
- New transformer capacities and replacement of old transformers (15%);
- Selective modernization of relay protection and automation (8%);
- Refurbishment of commutation equipment (7%).

Total necessary and planned sum for implementation of TSO investment program for the 2018-2020 period includes 32% from own funds and 68% from external sources.

Currently in Republic of Moldova there is no secondary legal framework regarding electricity balancing market as well as there are limited possibilities for system services suppliers on the right bank of Nistru river (there is need for a study regarding necessary balancing power in order to overcome the intermittence of wind and solar power plants connected to public electricity grid).

Development of production fleet by integration of renewable electricity sources as well as construction of Back-to-Back stations leads to increase of electricity security of supply of Republic of Moldova.

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