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Chapter 12

Photovoltaic Power Plant Grid Integration in the Romanian System–Technical Approaches

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/62739

Abstract

Technical issues of the integration of distributed generation (GD) in distribution networks are related to effects on power service quality (supply reliability, network voltage changes), power flows and network losses. The aim of this chapter is to perform a technical and economic evaluation of the impact that the connection of a Photovoltaic (PV) Power Plant has upon the electric energy distribution network in the distribution operator (DO) area. Additionally, the study also examines the effects on final consumers. The approach starts from general considerations and it continues with their practical application in a case study.

Keywords: impact on the electric grid, power flow, power quality, PV Power Plant, reliability

1. Introduction

Over the past decades, worldwide interest in renewable energy sources has risen significantly. Limitation of fossil fuels (oil and gas), such as the increasing cost of these primary energy sources and their impact on the climate change have stimulated interest in the area of alternative electrical energy supplies. Currently, the share of decentralized power systems in the electricity infrastructure has increased considerably [1-8].

The alignment of Romania's legislation to the European energy policy is achieved by investments mainly focused on building photovoltaic plants with megawatts generation capacities. The need to maintain the performance standards in electricity supply to consumers by distribution operators (DO), to which most of photovoltaic (PV) power plants are connected, requires an analysis of the impact that they have upon power distribution network.

The chapter aims to perform a technical and economical impact that the connection of a PV power plant has upon the electric energy distribution network in the DO area.

Other researches in this field are focused on integration, design or impact [1-7] of PV power plants [1-7].

2. Photovoltaic (PV) power plants situation at the Romania national level

Nationally, until 21 January 2014, according to Transmission and System Operator (TSO) - TRANSELECTRICA records, the PV power plants in use in our country are connected to the electrical distribution network with a maximum injection power of 835,076 MW, while those connected to the electrical transport network have an injection power of 24,562 MW. The PV power plants have a geographical distribution that covers most of the country, except for the mountain areas or the north and northeast parts of the country (Figure 1).

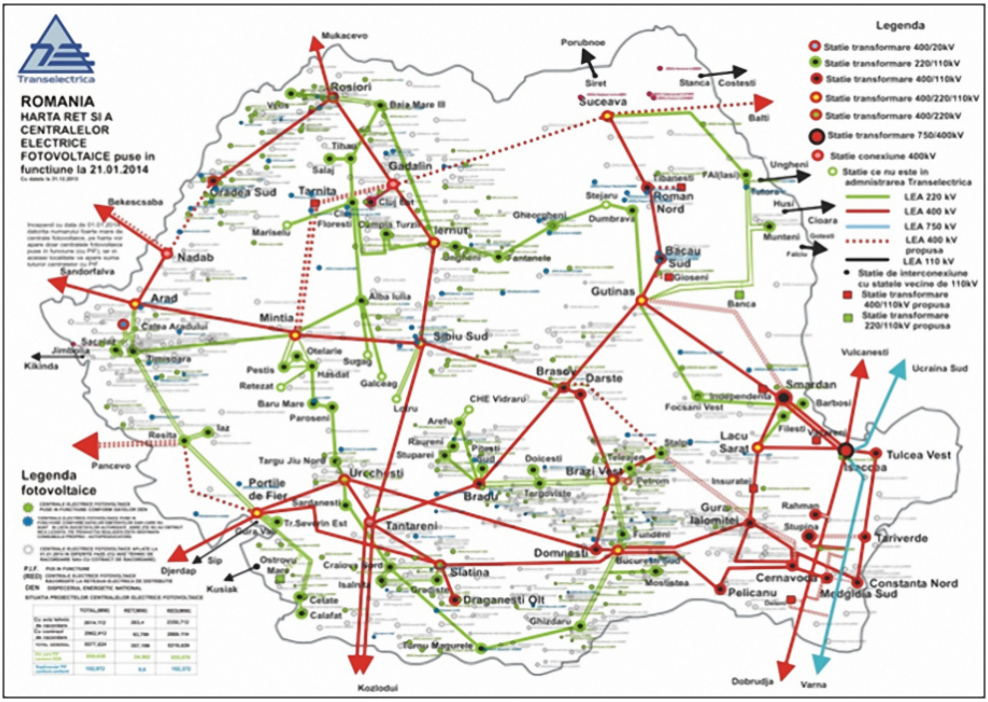

Figure 1. Transmission grid and PV power plants map.

During winter, for the National Power System (NPS), the consumption is considered as peak load, so according to data from TSO on 21 January 2014, the consumption at national level was in the range of 8212 MW to 8762 MW, a value of cumulative electricity generation of all producers, resulting in a surplus of 549 MW of power.

These readings are instantaneous values recorded at 1:04 p.m., the time when the production of electric power from PV power plants has the highest relevance, being this particular time of a winter day when the PV power plants produce the maximum power reported of installed capacity.

Figure 2 represents the production of electricity for the timeframe 9:00 a.m. to 7:00 p.m., according to generating technology types.

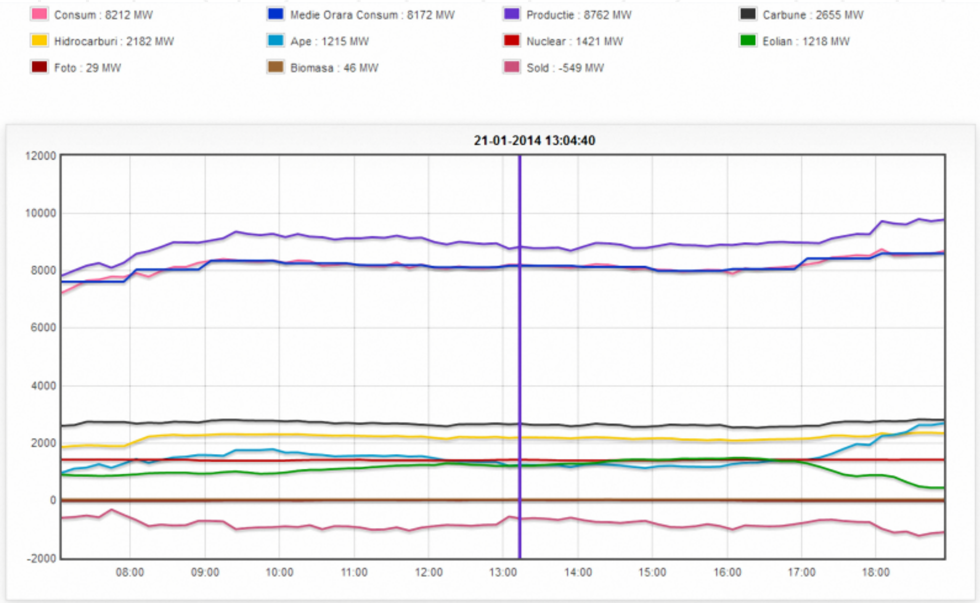

Figure 2. Generation-consumption instantaneous values for 21 January 2014.

Considering the entire winter period, when annual consumption is at maximum level and the PV power plants electricity production is 30% lower than the installed power, the PV power plants contribution to the total power compared to other types of producers is small: PV power plants – 0.33%, coal – 30.95%, hydrocarbons – 24%, hydro power plants – 14%, nuclear power plants – 16.2%, wind power plants – 14% and biomass – 0.52%.

The situation during the summer, when consumption is considered as base load, the differences are not significant, PV power plants operating at full capacity, noting that national consumption drops to an average of about 6000 MW.

Because a significant number of PV power plants, with an installed capacity of around 5500 MW, are not in use, their impact on the overall National Power System (NPS) cannot be analyzed in conjunction with the impact of other producers in the system.

Currently, in the Mureş County there are 15 PV power plants in operation, with a total installed power (P_i) of 25,626 MW, of which 13 are connected to the (DO) - medium voltage network (20 kV) - and 2 PV power plants are connected to the low voltage network of the same DO (Table 1).

P_i (MW)	<1 (MW)	1-2 (MW)	2-3 (MW)	3-4 (MW)
Number of PV	7	1	5	2

Table 1. Number of PV power plants in Mureş County and installed capacity

3. Minimal technical requirements of PV power plants for safe operation

The PV Power Plants, in addition to the Technical Norms governing the conditions for connecting the users to public electricity distribution ("Technical Code of Transport Network" [9] and "Technical Code of Electrical Distribution Networks" [10]), should also comply with the Technical Standard: "Requirements for the Connection to Public Electricity Networks for Photovoltaic Power Plants" [11] issued by Regulatory Authority for Energy (ANRE).

To ensure the safety operation of both the NPS and the PV power plants, the PV power plants fall into two categories, depending on the installed power: non-dispatchable power plants (NDPV) (that complies with the installed power $P_i \leq 5$ MW) and dispatchable power plants (DPV) ($P_i > 5$ MW). Their connection to public electricity networks requires mandatory compliance with certain technical requirements before putting them into service and afterwards.

The following necessary requirements must to be respected by DPV power plants:

- DPV power plants must be capable, at the common connection point (CCP), for an indefinite time, to produce simultaneously active and reactive maximum power according to the weather conditions, with respect the equivalent PQ performance diagram, the frequency range 49.5-50.5 Hz and the admissible range of voltage;
- All the inverter components of a DPV power plant must have the following capabilities:
    - To remain connected to the network and run continuously, in the frequency range 47.5-52 Hz;
    - To remain connected to the main electrical network when a variation of up to 1 Hz/second of frequency occurs;
    - Continuous operating voltage in the range of 0.9-1.1 of nominal voltage;
- DPV power plants and the inverters components must remain functional during voltage drops and voltage deviations (Figure 3);

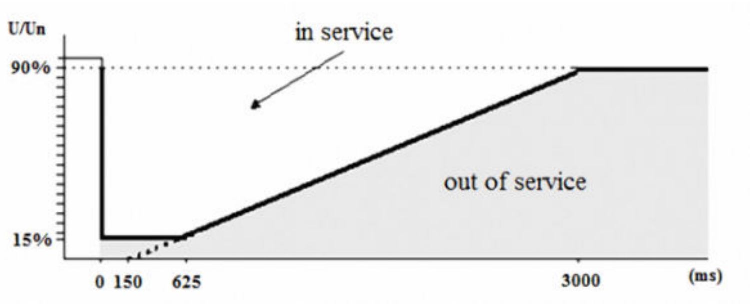

Figure 3. Magnitude of voltage drops for safety operation of DPV power plants and inverters.

- DPV power plants will be provided with automatic active power-frequency regulator. This will act as a frequency-active power response curve, exemplified in Figure 4, where P_m represents the instantaneous value of power. The coordinates of points A, B, C, D and E depend on the frequency value, on the active power that the plant can generate, and on the limit of active power preset value, in the ranges: A (50-47 Hz), B (50-47 Hz), C (50-52 Hz) and D and E (50-52 Hz). The position of the points must be set as requested by the network operator with a maximum error of ± 10 mHz;
- During voltage drops, all the inverters must inject maximum reactive power for a minimum of 3 seconds without exceeding the operating limits of DPV power plants;
- Modification of the active power generated because of frequency deviations will be made, as much as possible, in solar radiance conditions by adjusting the generated active power. If the frequency reaches a higher value (corresponding D-E on the characteristic curve), the DPV power plant can be disconnected;
- The active power generated by a DPV power plant must be limited to a preset value: DPV power plants must ensure that the active power at the CCP operate inside of ± 5% of the installed power of the power plant and must have the ability to set the deviation rate of active power at a value required by the TSO (MW/minute);
- DPV power plants must be equipped with reliable and secure protection systems, to protect against faults in electrical network, as well as against faults in the NPS;
- DPV power plants holder is required to protect the photovoltaic panels, inverters components and auxiliary installations against damage that may be caused by faults in their own installations or by the impact of the grid, to the correct operation of triggering the PV power plant protections or the network failures;
- In steady-state operation of the network, DPV power plants must ensure a voltage deviation inside its limits (between ± 5% of the rated voltage).
- The solution for the connection of PV power plants should not allow the operation in islanded mode. This involves disconnection of the PV power plants from the network as a result of the disconnection of the power supply stations to which the plant is connected.

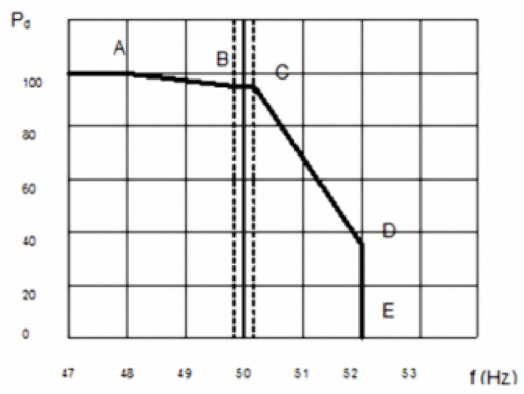

Figure 4. Active power and frequency deviations.

4. Case study: Chirileu PV power plant 3.2 MW

As a particular case study we analysed the impact of a photovoltaic power plant on the grid to which it is connected. For this study we selected the Chirileu PV Power Plant with an installed capacity of 3.2 MW connected to the 20 kV overhead electric line (OEL), Ungheni-Cipău and supplied from 220/110/20 kV Ungheni station system [12].

4.1. General data of Chirileu PV power plant

The PV power plant is located on an area of approximately 56,000 m^2 in the Chirileu village, Mureş County. The plant is located 9.6 km from 220/110/20 kV Ungheni station and 12.7 km from Cipău supply point.

The general technical data of the photovoltaic power plant are as follows:

- Installed power, $P_i = 3.2$ MW ;
- Apparent power, $S = 3.33$ MVA ;
- Nominal voltage (voltage in connection point), $V = 20$ kV;
- Net power injection in distribution energy network (DEN), 3.2 MW;
- Power factor, $cos\ \Phi$: 0.96 capacitive / 0.96 inductive;
- Estimated annual energy supplied to the system, $W = 4.262$ MWh;
- Installed power usage time, $T = 3.65$ hours / day (1332 hours/year);
- Daily operating mode in summer, T_a = maximum 12 hours/day; daily operating mode in winter: T_w = maximum 2 hour/day.

http://dx.doi.org/10.5772/62739

To emphasize the production capacity of the PV Plant, a power and energy production report for 11 July 2013 (Table 2) cumulative for the entire plant and of all inverters operating at full capacity, was generated. The total energy production was 22.27 MWh with operation at nominal power (3.2 MW).

The daily power and energy production graphics of the Chirileu PV Power Plant are presented in Figures 5 (summer) and 6 (winter).

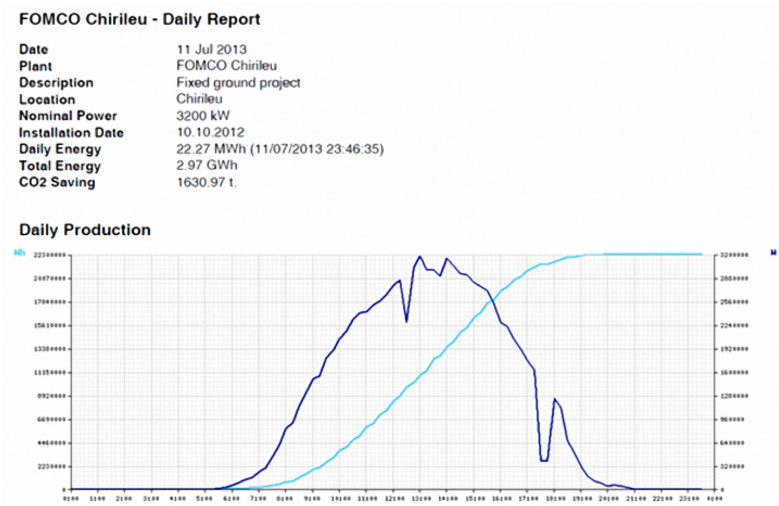

Figure 5. PV power plant energy production chart – Summer.

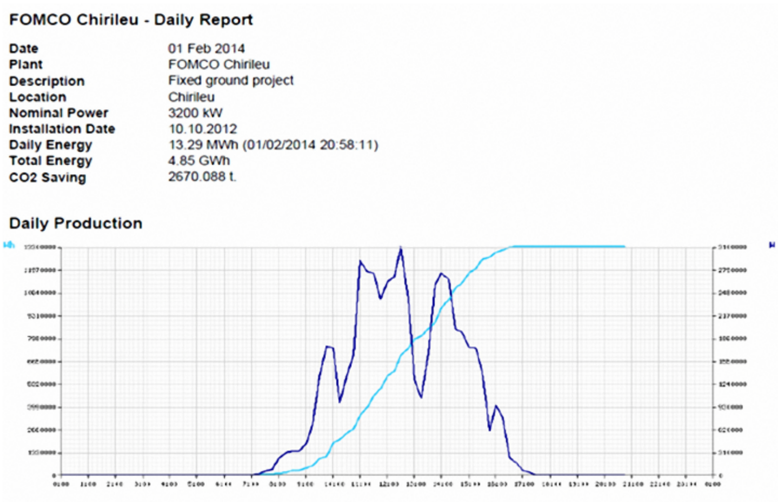

Figure 6. PV power plant energy production chart – Winter.

Energy/Power recorded data		
Hour	**Energy (Wh)**	**Power (W)**
2013-07-11 05:40:00	5	100
2013-07-11 06:00:00	4174	29,800
2013-07-11 07:00:00	104,825	190,600
2013-07-11 08:00:00	482,515	661,200
2013-07-11 09:00:00	1,488,494	1,360,000
2013-07-11 10:00:00	3,135,034	1,951,200
2013-07-11 11:00:00	5,451,184	2,478,400
2013-07-11 12:00:00	7,868,025	2,733,500
2013-07-11 13:00:00	10,346,612	1,450,500
2013-07-11 13:10:00	10,745,461	3,174,300
2013-07-11 14:00:00	13,160,949	2,937,500
2013-07-11 15:00:00	15,774,228	2,875,300
2013-07-11 16:00:00	18,364,122	2,401,000
2013-07-11 17:00:00	20,422,601	1,847,600
2013-07-11 18:00:00	21,387,377	477,400
2013-07-11 19:00:00	22,091,317	413,900
2013-07-11 20:00:00	22,234,959	57,500
2013-07-11 21:00:00	22,265,127	1900

Table 2. Energy/power recorded data of PV power plant (11 July 2013).

4.2. Network topology and characteristics

4.2.1. Network topology and characteristics of 20 kV Ungheni-Cipău OEL

The 20 kV OEL Ungheni-Cipău, 20.7 km long, comprises a conductor AlOl 70/12 mm^2 (between towers 1 and 127) and AlOl 50/5 mm^2 (between towers 128 and 239) (Figure 7).

The power transport capacity of the 70 mm^2 OEL cross-section conductor is 7.8 MVA, and the economic power transport capacity is 7.2 MVA. The power transport capacity of the 50 mm^2 and OEL cross-section conductor is 6.1 MVA and the economic power transport capacity is 5.8 MVA.

The 20 kV OEL parameters (Ungheni-Cipău) are as follows:

- Length: 20.7 km;
- Resistance (per phase, per km): 0.43m (Ω/km);

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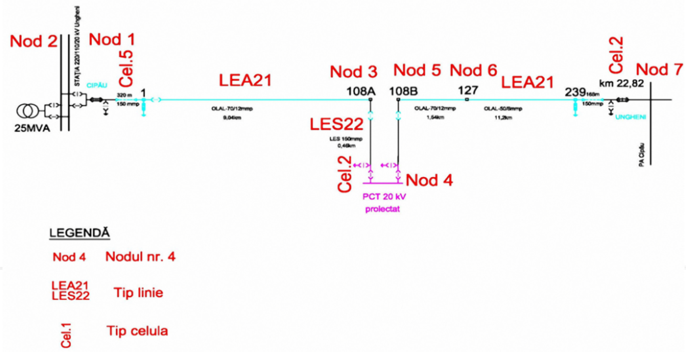

Figure 7. 20 kV OEL Ungheni-Cipău.

- Reactance (per phase, per km): 0.373 (Ω/km);
- Geometric mean distance (GMD): 1764 (mm).

4.2.2. Loads for 220/110/20 kV Ungheni station and 20 kV Ungheni-Cipău OEL

In 220/110/20 kV Ungheni system station from Figure 8 (that belongs to TSO), 110/20 kV, 25 MVA transformer (Transformer 1)- had, in January 2013, a 13.91 MW (winter peak load-WPL) and a 11.43 MW (summer base load-SBL) in July 2013. The 20 kV Ungheni-Cipău OEL had a 2.74 MW (WPL) in January 2013 and 1.94 MW (SBL) in July 2013.

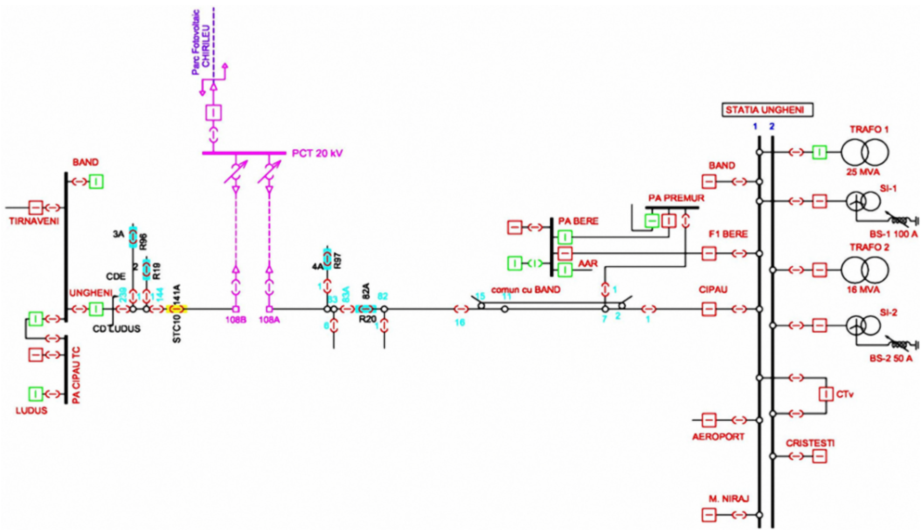

Figure 8. Ungheni system station and OEL 20 kV Ungheni-Cipău.

At 20 kV, Ungheni-Cipău OEL is connected to 39 consumers with a total installed apparent power 9.89 MVA.

The power dispatcher of the DSO provides that the nominal voltage on 20 kV Ungheni-Cipău station should be maintained at around 20.6 kV. This value is imposed so that the voltage drop should not exceed (-5%) the nominal value of the standard voltage.

4.2.3. Reserve loads for 20 kV OEL and Transformer 1 of Ungheni 110/20 kV Station

The load reserves of both line and the Transformer 1 from the station are presented in Table 3, considering the maximum power supplied by Chirileu PV Power Plant and the admissible load. The OEL relates to economic transport capacity (70 mm^2 cross section) and the optimal charging state (appropriate for minimum power losses) of transformer, considered at 75% of nominal apparent power (25 MVA).

Equipment	**Existing load (MW)**	**PV Power Plant contribution (MW)**	**Allowable load (MW)**	**Reserve load (MW)**
Ungheni–Cipău 20 kV OEL **(WPL)**	2.74	-3.20	6.62	0.68
Ungheni–Cipău 20 kV OEL **(SBL)**	1.74	3.20	6.62	1.68
220/110/20 kV Ungheni Station Tranformer 1 – 25 MVA **(WPL)**	13.91	-3.20	18.86	1.75
220/110/20 kV Ungheni Station Tranformer 1 – 25 MVA **(SBL)**	11.43	-3.20	18.86	10.63

Table 3. Load reserves of both line and the Transformer 1.

For the admissible load of 20 kV OEL, maximum load duration (T_M) of 2000 hours/year was considered, which covers the T_M duration required by the PV Power Plant, of 1332 hours/year.

4.3. Technical impact of PV Power Plant upon distribution power network

4.3.1. Setting the voltage for the connection of the PV Power Plant

As a first step for connecting the plant to a transmission or distribution electric network, the calculation of the voltage step at the connection point is required, and that is done by calculating the moment of load, M_l.

$$\boldsymbol{M}_l(MVAkm) = \boldsymbol{S}_{\max}(MVA) \cdot L(km) = 33.4(MVAkm) \tag{1}$$

For a moment of load M_l = 33.4 (MVAkm) and the maximum power supplied inside limits (2.5 -7.5 MVA), according to Table 4, the PV Power Plant is within Class C, so it can be connected to the MV network (20 kV).

Class of power plant	Maximum load S_{max} (MVA)	Moment of load M_l (MVAkm)	Voltage step at connection point (kV)	User connection possibilities	
				Directly to grid network voltage(kV)	Through transformers
A	Over 50	Over 1500	400 220 110	- 220 110	400/110 kV 220/110 kV 220/MV kV 110/MV kV
B	7.5–50	Maximum 1500	110	110	110/MV kV
C	2.5–7.5	30–80	110 20	110 (20)	110/MV kV 20/6 (10) kV 20/0.4 kV
D	0.1–2.5	3-8	20 10 6	6-20	20/0.4 kV 10/0.4 kV 6/0.4 kV
E	0.03-0.1	Maximum 0.05	0,4	0.4	MV/0.4 kV
F	< 0.03	-	0,4	0.4	-

Table 4. Voltage step levels at connection point according to the required power.

The technical standards establish important criteria that are taken into account for the connection of users to public electricity networks, which determine the voltage step level and the connection point:

- The cost of works needed to achieve the connection;
- The technical requirements regarding operation and safety level of the electrical network;
- The requirements to maintain the power quality of the transmission and distribution network appropriate for all the consumers.

4.3.2. Calculation of network safety level in connection point

To calculate the reliability of equipments in the connection point, it is necessary to take into account the bus safety indicators of Ungheni 220/110/20 kV station (Table 5).

The parameter values of the reliability indicators for the equipments (cell line, measure, voltage transformer, current transformer) are presented in Table 6.

Station	Bus	Rate of failure (λ)	Rate of repair (μ)	Maximum duration of an interruption (h)
Ungheni 1	1-20 kV	0.007920	10,583.1	1.44
Ungheni 2	2-20 kV	0.00528	10,583.1	1.44

Table 5. Bus safety indicators of Ungheni 220/110/20 kV station

No.	Equipment/20kV network element	Rate of failure (λ)*10^-4	Rate of repair (μ)*10^-4
1	Disconnector	0.01	500
2	Circuit breaker, recloser	0.15	750
3	MR	0.14	750
4	Voltage transformer	0.011	250
5	Current transformer	0.003	500
6	Bus1 (New)	0.035	450
7	Bus 2 (Old)	0.022	600
8	20kV OEL	0.05	1200
9	20kV UEL	0.3	150

Table 6. Reliability indicators for the equipments

The calculation of the duration of interruption was performed according to the "Standard on Calculation Methods for Safety Operation of Power Plants and Devices" NTE 005/06/00 [13], using a specialized software (Figures 9 and 10).

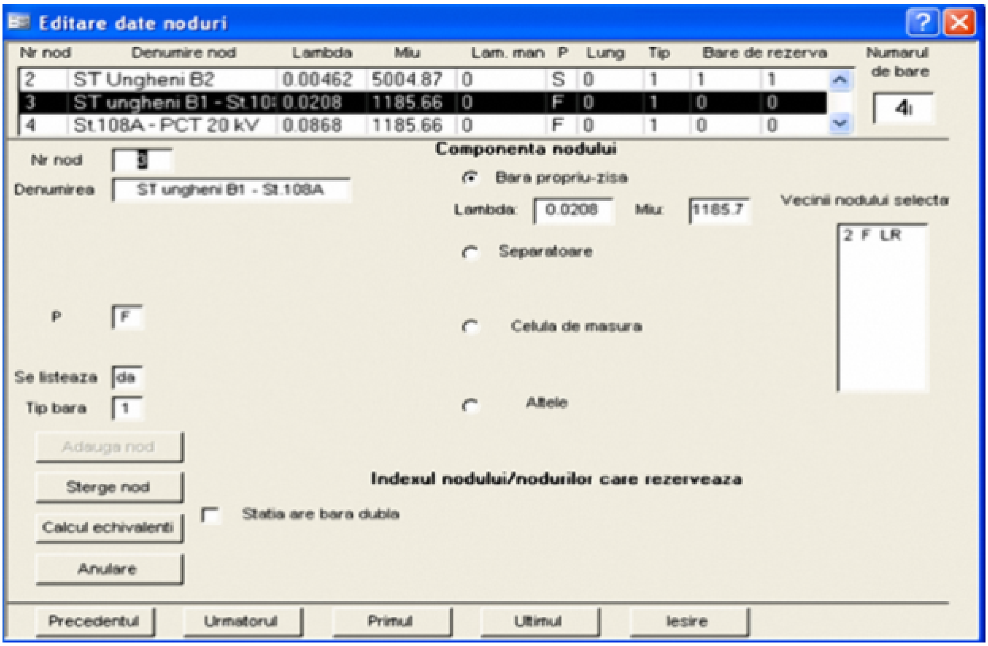

Figure 9. Graphical use interface-Buses data.

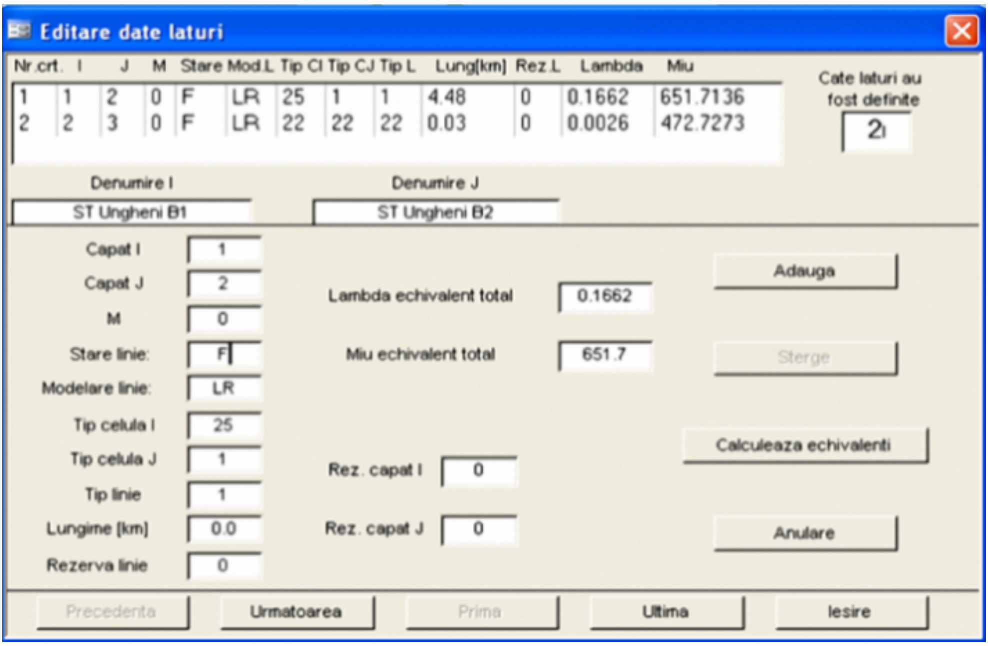

Figure 10. Graphical use interface-Branches data.

The following main results are highlighted:

- In the connection point, the maximum duration of interruption is 20.58 hours;
- The maximum duration of interruption in case of damage, in the Ungheni 220/110/20 kV station increases from 1.44 hours to 2.49 hours ;
- The maximum duration of interruption in the 20 kV connection point increases to 22.38 hours.

It can be concluded that the impact of Chirileu PV Power Plant connection to 20 kV Ungheni-Cipău OEL, in terms of reliability, is significant both in Ungheni station and in 20 kV Cipău connection point.

4.4. Load flow, power losses and voltage level analysis in steady-state conditions

To evaluate the impact of Chirileu PV Power Plant on NPS (in particular upon the 220/110/20 kV Ungheni station, Ungheni-Cipău 20 kV OEL and consumers connected to the electric line), the following input data must be taken into account:

- Network topology and characteristics of the area: Ungheni Station-Ungheni-Cipău 20 kV OEL – consumers;
- Typical daily loads in Ungheni station and typical daily loads on 20 kV Ungheni-Cipău OEL;

- Electrical energy production capacity of Chirileu PV Power Plant.

To perform the voltage drops, power flows and power losses, the maxim value of winter peak load (WPL) and summer base load (SBL), both in Ungheni station and 20 kV Ungheni-Cipău OEL, are considered in steady-state conditions.

Load flow studies for the power system's steady-state operation and development planning are performed to investigate MW and MVAR in the branches of the network and busbars (nodes) voltages [8].

In this case we analysed the evolution of voltage levels on the 20 kV Ungheni station bus, at the common connection point and at the end side of OEL, for two specific steady-state conditions:

- Peak load on 20 kV Ungheni-Cipău OHL, PV Power Plant in service;
- Base load on 20 kV Ungheni-Cipău OHL, PV Power Plant out of service.

Calculation of the power flow for 20 kV Ungheni -Cipău OEL is performed using NEPLAN software package [14] for the system (Figure 11), which allows for the design, simulation and management of electrical network. The solution of the power flow is obtained by means of the extended Newton-Raphson method due to the possibility of leading to an easier convergence process.

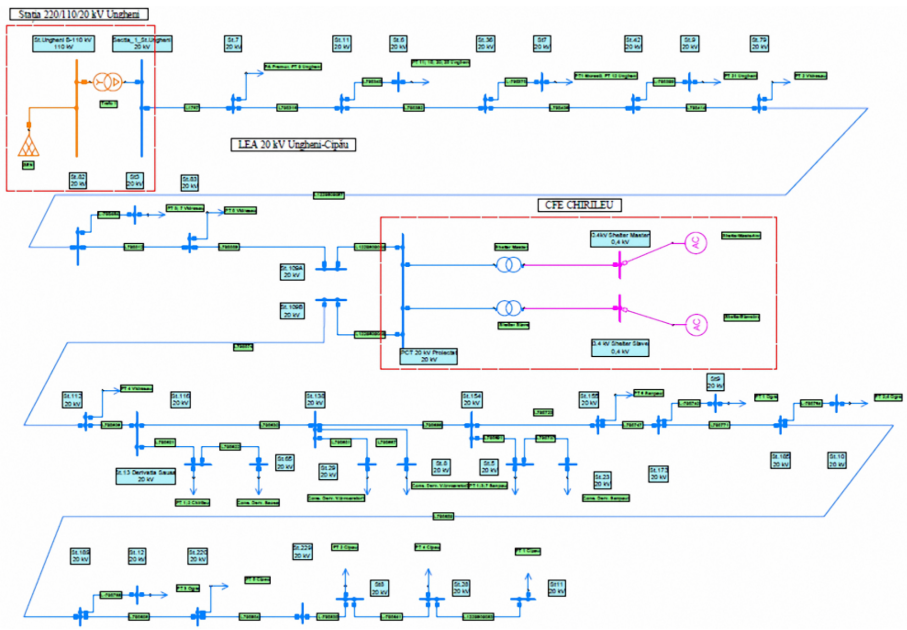

Figure 11. Line diagram of system in Neplan.

4.4.1. *Power flow and power losses results*

The summary simulation results for the two regimes, winter peak load (WPL) and summer base load (SBL), for two cases, PV Power Plant out of service and PV Power Plant in service, are presented in Tables 7-10.

P Loss (kW)	93.79	
Q Loss (kVAr)	348.79	
P Imp (kW)	2770.04	
Q Imp (kVAr)	1134.29	
P Gen (kW)	2770	
Q Gen (kVAr)	1134.29	
P Load (kW)	2676.2	
Q Load (kVAr)	785.5	
Iron Losses (kW)	31.68	
Un (kV)	**20**	**110**
P Loss Line (kW)	60.65	0
Q Loss Line (kVAr)	51.08	0
P Loss Transformer (kW)	0	33.14
Q Loss Transformer (kVAr)	0	297.1

Table 7. WPL-PV Power Plant out of service

P Loss (kW)	62.43	
Q Loss (kVAr)	413.18	
P Imp (kW)	-461.18	
Q Imp (kVAr)	1211.83	
P Gen (kW)	0	
Q Gen (kVAr)	0	
P Load (kW)	3137.5	
Q Load (kVAr)	-426.33	
Iron Losses (kW)	31.69	
Un (kV)	**20**	**110**
P Loss Line (kW)	30.5	0
Q Loss Line (kVAr)	24.49	0
P Loss Transformer (kW)	0	31.92
Q Loss Transformer (kVAr)	120.75	267.93

Table 8. WPL - PV Power Plant in service

P Loss (kW)	66.59	
Q Loss (kVAr)	310.25	
P Imp (kW)	1834.09	
Q Imp (kVAr)	1365.24	
P Gen (kW)	1834.09	
Q Gen (kVAr)	1365.24	
P Load (kW)	1767.5	
Q Load (kVAr)	1054.99	
Iron Losses (kW)	31.66	
Un (kV)	**20**	**110**
P Loss Line (kW)	34.11	0
Q Loss Line (kVAr)	28.37	0
P Loss Transformer (kW)	0	32.84
Q Loss Transformer (kVAr)	0	281.88

Table 9. SBL-PV Power Plant out of service

P Loss (kW)	82.3	
Q Loss (kVAr)	439.96	
P Imp (kW)	-1350.2	
Q Imp (kVAr)	1508.09	
P Gen (kW)	0	
Q Gen (kVAr)	0	
P Load (kW)	3117.7	
Q Load (kVAr)	-453.1	
Iron Losses (kW)	31.65	
Un (kV)	**20**	**110**
P Loss Line (kW)	50	0
Q Loss Line (kVAr)	42.6	0
P Loss Transformer (kW)	0	32.29
Q Loss Transformer (kVAr)	119.89	277.46

Table 10. SBL-PV Power Plant in service

4.4.2. Voltage level analysis

According to the Performance Standard for Electricity Distribution Service, the voltage deviation and admissible limits are presented in Table 11.

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Phenomenon	Admissible limits
Limits for contractual voltage U_c magnitude at MV and HV	Contractual voltage U_c inside voltage limits (± 5 %) of nominal voltage
Flicker	$P_{lt} \leq 1$, during 95% of a week
Fast voltage change magnitude in steady-state conditions	± 5 % of nominal voltage U_n at LV ± 4 % of U_c at MV and HV
Unbalance (negative component) - K_n	LV and MV, $K_n \leq 2$ %, for 95% of a week HV, $K_n \leq 1$ %, for 95% of a week
Frequency	50 Hz ± 1 % for interconnected network 50 Hz +(4% /- 6 %) for isolated network

Table 11. Voltage deviation limits

The results related to the voltage levels are presented in Table 12.

Loads / Network buses	Winter peak load-PV Power Plant out of service	Winter peak load-PV Power Plant in service	Summer base load-PV Power Plant out of service	Summer base load-PV Power Plant in service
20 kV Ungheni Station bus	20.5 kV	20.51 kV	20.49 kV	20.48 kV
Common connection point 20 kV	19.94 kV	20.61 kV	20.03 kV	20.50 kV
PT 1 Cipău – end side of OEL	19.74 kV	20.40 kV	19.86 kV	20.33 kV

Table 12. Buses voltage magnitude results

The power flow results for the two regimes, winter peak load (WPL) and summer base load (SBL) are presented in Table 13.

Power flow on 20 kV Ungheni Station bus		
Steady-state condition	**P (kW)**	**Q (kVAr)**
Winter peak load - PV Power Plant out of service	2736.89	836.58
Winter peak load - PV Power Plant in service	-493.24	943.39
Summer base load - PV Power Plant out of service	1801.01	1083.36
Summer base load - PV Power Plant in service	-288.45	1214.85

Table 13. Power flow results

Due to transit of power produced by the plant, which is supplied on the 20 kV Ungheni Station bus, the power losses in the electric line increase, as presented in Table 14.

Steady-state condition	Active power losses (kW)
Winter peak load - PV Power Plant out of service	60.65
Winter peak load - PV Power Plant in service	30.5
Summer base load - PV Power Plant out of service	50
Summer base load - PV Power Plant in service	34.11

Table 14. Power losses results

4.4.3. Financial analysis - impact of Chirileu PV power plant

The interruptions of electricity supply service result in financial losses, from the producer's point of view. According to the results of calculation of reliability indicators, the maximum duration of an interruption, in case of a fault to the point of connection, is about 20 hours.

According to the DSO performance standards, a specific quality indicator is calculated: EENS - electrical energy not supplied, defined as the total energy not supplied by the producer (PV Power Plant) to the users, due to interruptions:

$$EENS = \sum_{i=1}^{n} P_i \cdot D_i = 1.4 \cdot 16 = 22.4(MWh) \qquad (2)$$

where:

P_i - non-delivered power, due to interruptions (the average of the active power non- generated by PV Power Plant (1.4 MW);

D_i - interruption duration that is considered relevant during the time when PV Power Plant is out of service (e.g., summer, 16 hours/day).

The price of a green certificate is 130 Lei/MWh, and the producers receive two green certificates for each MW and an extra 170 Lei/MWh, the price of energy traded on the free market.

$$Losses(Lei) = 22.4MWh \cdot (2 \cdot 130) + 22.4 \cdot 170 = 9632(Lei / \text{int}erruption) \qquad (3)$$

5. Conclusions

Electricity produced by conventional, large scale central generation requires HV transmission networks such as HV, MV and LV distribution networks to reach its consumers, while DG, often located at the MV busbars and closer to load, requires transporting facilities, may reduce network losses and increase service quality.

The work presents and explores both of general and particular issues related to:

- State-of –the art of PV power plants at Romanian national level and specifically at the study area: electricity balance, structure, connection and integration in the electrical network.
- Technical conditions required for the connection of PV Power plants such as electric power networks in order to reach the criteria of reliability, power quality and economy.
- Case study regarding the impact of a PV power plant on the electric grid to which it is connected. The study is performed upon the photovoltaic power plant with an installed capacity of 3.2 MW connected to the 20 kV OEL and supplied from a 220/110/20 kV station.

The results provide a complete overview of the situation from a technical (safety and power quality) and economical point of view. The results may be also be used as a basis for development plans of future Distributed Generation Sources.

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