ASSESSMENT THE IMPACT OF PVS UPON ELECTRICAL VALUES FROM CCP IN BCPS

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Abstract - The influences of distributed electrical energy sources based on renewable energy resources over the power transmission and distribution systems are varied. The possible effects are more pronounced in the case of electricity generated using solar and wind resources, given the specificity and intermittency of the power produced from these resources. Photovoltaic systems (PVS) are one of the most promising renewable energy solutions. In case of the grid connected photovoltaic systems, these could provide many benefits to the network utilities. This paper intends to present the effects of PVS upon the power quality (PQ) parameters carried out in case of a radial distribution network within Bihor County Power System (BCPS), by analyzing the results of the measurements performed upon the electrical parameters from the point of common coupling (CCP) where these PVS are injecting the produced power. Measured values are compared with the limitations set in the international standards and the technical code of distribution networks, respectively the connecting conditions stipulated regarding these sources.

Keywords: photovoltaic systems, power distribution systems, electrical parameters, power quality.

1. INTRODUCTION

Concerns about environmental problems due to the use of fossil energy resource (FES) and research to identifying new sources of sustainable energy, in the last decades have led to an increasing use of renewable energy resources (RER) [4][11][14]. Electrical renewable energy sources (E-RES) means electrical energy from RER, namely wind, solar, geothermal and hydrothermal, ocean energy, hydropower, biomass, landfill gas, sewage treatment plant, gas and biogases [7].

Nationally evolution of PVS

From these different types of E-RES based on RER, in the past decade, the electrical energy (EE) obtained from wind and solar resources basically have experienced exponential growth in Romania between 2010 and 2014. The EE from photovoltaic sources (PVS) has increased more than 1000 times [5].

In spite of the fact that in 2007, the total production of electricity was approximately 64,7 TWh, according to the statistical data published by Romanian Energy Regulatory Authority (ANRE), regarding the production of EE in terms of E-RES, Romania had only total production of 17,08 GWh from RER, compound 99.9% from hydro-electric power plants (HEPP) and 0.1% wind, according to ANRE. It can be noticed the fact that at the level of 2008 E-RES was practically produced exclusively within HEPP power plants and reached only 26,4 % from the amount of EE production, with mention that the HEPP amount is almost entirely represented by the large hydro power plants, who do not receive any subvention, with installed capacity over 10 MW. In conclusion, in 2008 the share from total EE production in Romania, in terms of E-RES [7] was basically inexistent.

During the last five-year period 2008–2014, installed capacity of RER technologies grew very rapidly, with the fastest growth in the power sector, sustained by the several government decisions adopted and promotion scheme, such as the Green Certificates (GCs).

According to grid operator Transelectrica, Romanian renewable projects reached 4412 MW installed capacity by January 2014: the wind sector had 2704 MW, while the photovoltaic sector has grown to 1171 MW; the hydroelectricity sector had 536 MW, while biomass edged close to 100 MW [9].

In recent years, Romania has begun to re-establish itself as a major user of PV systems. The evolution of the installed PV capacity in Romania is presented bellow, in the Figure 1, according the data from [9].

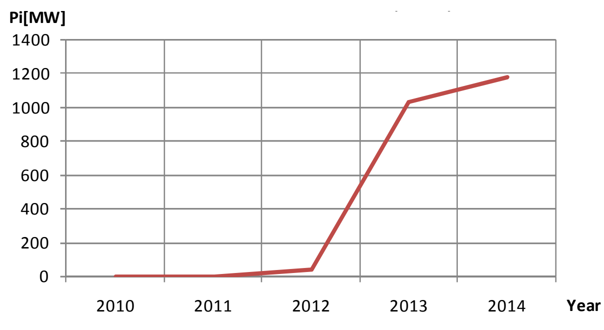

Fig. 1 - Evolution of the installed PV capacity [5]

Romania is situated in the European's "B" sunlight zone, which gives the country a major solar potential waiting to be tapped. Romania is eligible for annual energy flow between 1000 and 1300 [kWh/m2/year].

Evolution of PVS within BCPS

The BCPS is a part of the National Power System and works interconnected. Transmission and distribution activities are provided by the Local Branch of S.C. F.D.E.E. Electrica Distributie Transilvania Nord S.A., the main distribution operator in the North-Western part of Romania, through high, medium and low voltage installations across Bihor County.

Regarding the situation before spreading the PVS, in terms of the years 2010, the BCPS consists from:

- 31 – Electrical Substations (ESS) [110 kV];
- 68,2 [km], EHV power lines[400 kV];
- 803,52 [km], HV power lines and cables[110 kV];
- 2916,55 [km] Medium Voltage lines;
- 731,03 [km] LES Medium Voltage cables;
- 2264 transformers;
- 6 small hydro-power stations (SHPS).

In the next period, between 2011 and 2013 many renewable energy sources was installed in Bihor County, such as:

- Hydro power plants, at the end of 2013, 16 units, with 35 groups with a total installed capacity of 227,158 MW;
- 45,872 MW installed capacity in PVS, from 19 PVS connected to the grid, from the total of 126,312 MW installed in 47 PVS.

Regarding the geographic location of PVS within Bihon County, in the Figure 2, we have placed the most important PVS in terms of installed capacity.

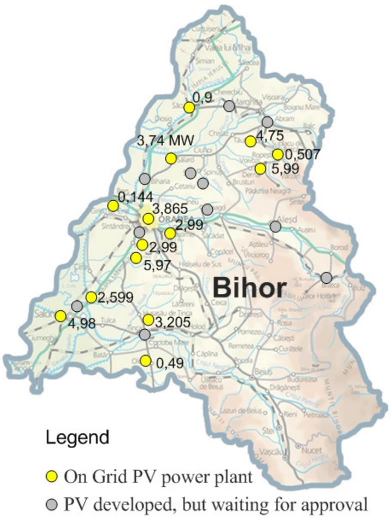

Fig. 2 - PVS localization in Bihor County[5]

In case of energy industry, many years the major development direction was limited to the certainty that the energy must be produced centrally in large power plants, then delivered for the consumption areas through transmission lines and finally to consumers through distribution lines, at the lower voltage levels. In case of this system, energy flows is unidirectional from high voltage to low ones.

Currently, the model is changing and becoming from the one-way to bidirectional network of distributed generation [1]. The potential problems associated with grid connected PVS are well known [2]. Operation of a distribution system that has a large number of units distributed generation presents several problems, such as:

- voltage profile varies along the network, depending on the power produced and consumed in the system, leading to a different behavior from unidirectional network;
- transient voltages appear as a result of connecting and disconnecting of generators or as a result of their operation mode;
- power quality and reliability may be affected;
- short-circuit levels can increase;
- power losses are changing depending on production and load levels;
- protective measures of powered utilities and the protection of distributed generators must be coordinated;

Taking all these factors into account, this paper presents measurements performed on a distribution network in CCP in order to evaluate the impact of the considered PVS, regarding the voltage levels, power factor and the effects on the Flicker level.

2. WORKING METHODOLOGY

In order to measure and record the tracked electrical parameters, the used measuring equipment was a network analyzer named Visa Power manufacturer by Dranetz.

To process and analyze the data obtained by the network analyzer, the Dran-View, version 6, software package was used, which is a program for Windows operating systems which offer quick, easy viewing and analyzing energy monitoring tools.

Regarding the influence on the voltage level, the objective was to examine and analyze the voltages levels variations according to the technical code of distribution network, in terms of the existing regulations [6]. The requirements from the EN 50160 standard must be met by distributed generation units, such as photovoltaic. These requirements are not difficult to meet. For example, the parameters supply voltage must be within certain limits for 95% of the test period, while the remaining period of 5% deviation may be higher. The average for 95% of the time should be between 90% and 110% of rated voltage.

Illustration of a voltage dip and a short supply interruption, classified according to EN 50160 is presented in the Figure 3.

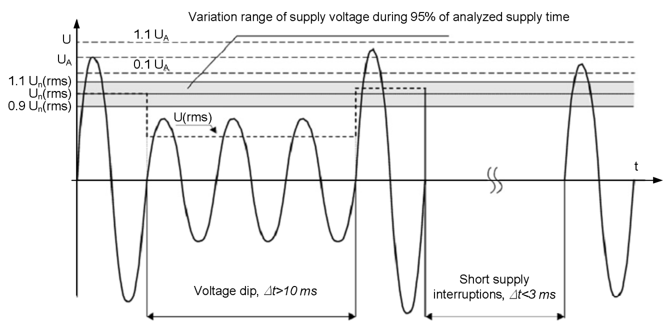

Fig. 3 – Illustration of a voltage dip and a short supply interruption

Where [6][4][7]:
U_n – nominal voltage of the supply system (rms);
U_A – amplitude of the supply voltage;
U(*rms*) – the actual *rms* value of the supply voltage.

The power factor, defined as the ratio of active power P and apparent power S of the system, show a particular interest for electricity producer and the transporter, supplier and end user because it influences the performance and costs of electricity supply, even if not a necessity stipulated in EN 50160. In case of the sinusoidal regime it can be defined as the cosine of the angle between voltage and current. A low power factor causes additional power losses in the system at the same active power flow, can reduces the available power in the system and has a negative influence regarding the system stability.

With the voltages situated in the admissible range, in the common coupling point the reactive power produced / absorbed by a PVS in operation must be continuously adjusted corresponding to a power factor of 0,90 capacitive and 0,90 inductive in absolute values.

Depending on the technology PVS can have normally some additional capacity reactive power, although reactive power available depends on the generated active power. This dependence is expressed by PQ diagrams. Additional, reactive power capability can be used in automatic control voltage-reactive power, this must be set to operate in "voltage control in the CCP" or "reactive power control" exchanged with the grid in the CCP. Whatever option is chosen, renewable power shall meet the requirement of having zero reactive power exchange in the CCP, when the active power generated is zero.

Flicker is considered one of the most significant effects of voltage fluctuation because it can affect the production environment by causing personnel fatigue and lower work concentration levels. Flicker is a subjective impression of the discontinuity of visual perception caused by a variation of voltage. The flicker can be measured by a flicker meter that based on a reproduction of a 60 W incandescent lamp, the sensitivity of the human eye and the corresponding brain reaction. For the evaluation of the emissions different flicker limit curves have been determined. The reasons for flickers are voltage fluctuations, whereby the curve form of this variability and the frequency are essential.

According to the EN 50160 standard, Flicker is characterized and standardized by the severity of the short-term flicker (P_{ST}), measured over a period of 10 minutes, with specialized equipment, respectively long-term (P_{LT}), calculated over a period of 2 hours (12 intervals of 10 minutes). The relations for the P_{LT} according the PST are shown to the following expression (1) [12].

$$P_{LT} = \sqrt[3]{\sum_{i=1}^{12} \frac{P_{STi}^3}{12}} \qquad (1)$$

*Note: Usually, the standards do not specify limits for higher order harmonics (over 25), because they have a very small value, but unpredictable because of resonance phenomena.

In accordance with standard EN 50160, Flicker must have values $P_{LT} \leq 1$ on the level of long-term on a minimum of 95% per week.

3. CASE STUDY

In order to evaluate the impact of grid connected PVS upon electrical values from CCP, one PVS with an installed capacity of 4992 kW were analyzed. The PVS is located near Salonta, Bihor County, at 1,75 kilometers from the local power station with the common coupling point set at 20 kV voltage level, in a node of the Salonta – Oradea, double-circuit power transmission line.

The analyzed PVS, consists of a total of 20784 photovoltaic panels (PVP), with 0,240 kW each one, polycrystalline type, model SYP240S manufactured by Risen Energy Co., Ltd. from China. The installed capacity for own consumption is 40 kW. Some of the main characteristics of the PVP, for Standard Conditions (STC), are presented in the Table 1.

Table 1. –Clectrical characteristics of PVP at STC

Characteristics	Value	Units
Maximum Power	240	W
Maximum Voltage	30,20	V
Maximum Current	7,69	A
Open Circuit Voltage	37,20	V
Short Circuit Current	8,33	A
Module Efficiency	>14,78	%

Performance at STC means the Irradiance of 1000W/m, PVP temperature 77±3.6°F (25±2°C), power measurement tolerance: ±3% AM 1.5.

The Nominal Operating Cell Temperature (NOCT) is defined as the temperature reached by open circuited cells in a module under the conditions, irradiance on cell surface = 800 W/m^2, air temperature = 20°C, wind velocity = 1 m/s, PVP with open back side. Characteristics of the PVP for NOCT, are presented in the Table 2.

Table 2. – Characteristics of PVP at NOCT

Characteristics	Value	Units
Maximum Power	173,04	W
Maximum Power Voltage	26,56	V
Maximum Power Current	6,52	A
Open Circuit Voltage	33,65	V
Short Circuit Current	6,8	A

The PVP temperature affects the maximum power output directly. As PVP temperature increases, its output current increases exponentially while the voltage output is reduced linearly. The power loss due to temperature depending on the type of used solar panel. Temperature coefficients are presented in the Table 3.

Table 3. – Temperature coefficients

Characteristics	Value	Units
Temperature Coefficient Voc	-0.33%	°C
Temperature Coefficient Isc	+0.033%	°C
Temperature Coefficient Pmpp	-0.39%	°C
Normal operating temperature	45±2	°C

Main permitted operating conditions/restrictions are presented in the Table 4.

Table 4. – Permitted operating conditions

Characteristics	Value	Units
Maximum system voltage	1000	V(DC)
Operating temperature	-40~+85	°C
Maximum mechanical load	5400	Pa
Resistance against hail	25	mm
	23	m/s

As it is well know, the electrical characteristics of PVP's varies under the different irradiations levels but also depends of the cell temperature level. The variation curves for the model SYP240S are presented in the Figure 4, in case of constant cell temperature at 25°C, respectively, the IV curve under the cell temperature variation in Figure 5.

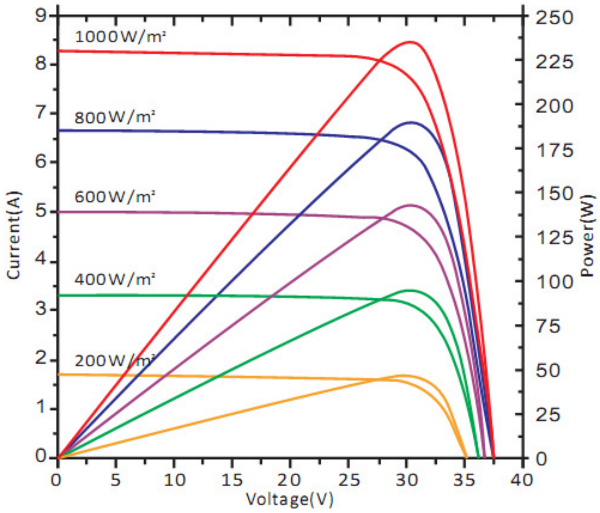

Fig. 4 - Electrical characteristics at different irradiations (temperature is constant = 25 °C)

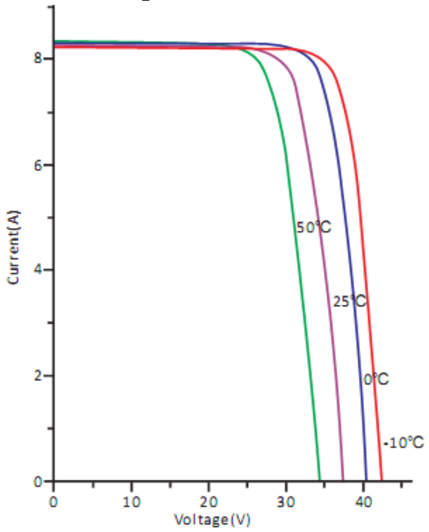

Fig. 5 – IV Characteristics at different cell temperatures (AM 1.5, 1000 [W/m])

The PVS contains 20 central power inverters, type RS I20-0460-3, manufactured by Vacon, with the efficiency curve presented in Figure 6. The maximum power of the inverter is 255 kW on the DC side, with the maximum continuous voltage 911 V, respectively, maximum current of 561 A. The Maximum Power Point Tracking (MPPT) voltages are between 460÷850 V.

The maximum power is 250 kW on AC side at a voltage of 320 V. The maximum output current is 460 A, at the nominal output frequency of 50/60 Hz. The power factor is rated at 0,99 and the maximum efficiency is 98.00 % at 450 V DC.

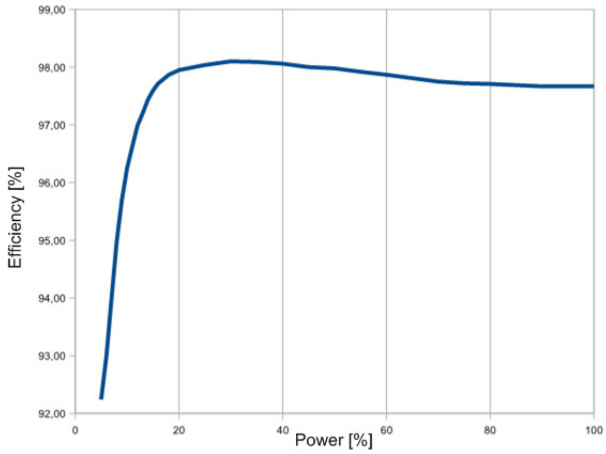

Fig. 6 – Central inverter efficiency curve

Evacuation of the produced power is performed through 5 power transformers 1000 kVA, 20/0.32 kV, 50 Hz, Dy-n1, uk = 6%. Each transformer is connected, on the low voltage side to 4 different branches, each containing a three-phase VACON type inverter. Each inverter had a superstring box on the DC side. One of the five branches is represented schematic in the Figure 7.

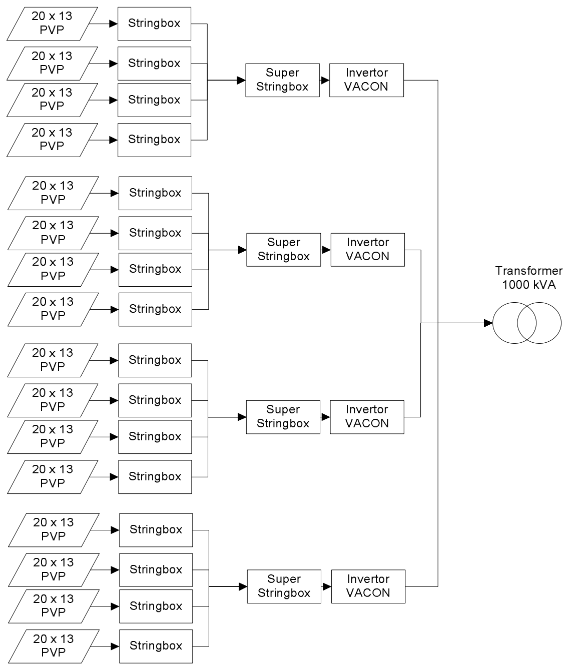

Fig. 7 - Schematic representation of single branch connections

Analysis of the influence on the voltage level

After processing and analyzing the measured data, it was found that the voltage is within the considered limits.

Based on the measured values, and the compliance report generated some additional information can be extracted, such voltage dips, existing interruptions and peaks exceeding the nominal values of the voltages (*SWEELS*) during the reference 1 week measurements, according to EN 50160, as it is shown in Figure 8.

EN50160 COMPLIANCE REPORT - ADDITIONAL INFORMATION
Site: PowerVisa Site, Week #1 (10/03/2014 00:00:00.0 to 10/10/2014 00:00:00.0)

Supply Voltage Dips, Interruptions and Overvoltages
(EN50160 does not specify limits for this category, these are informative figures)

Magnitude	10-100 msec	0.1-0.5 Sec.	0.5-1 Sec.	1-3 Sec.	3-20 Sec.	20-60 Sec.	1-3 Min	>3 Min
Dips:								
0% - 10%	8	16	-	-	-	2	-	12
10% - 15%	18	9	4	-	-	-	3	6
15% - 30%	21	12	18	4	-	4	-	9
30% - 60%	33	3	-	-	-	-	1	3
60% - 99%	127	11	2	3	-	-	-	7
Interruptions:								
99% - 100%	6	4	-	-	-	6	12	9
Swells:								
0% - 110%	-	-	-	-	-	-	-	-
110% - 120%	8	7	-	5	2	1	2	24
120% - 140%	23	19	1	3	11	4	22	152
140% - 160%	25	40	-	-	-	1	4	21
160% - 200%	22	26	2	14	2	18	15	65
200% -	6	4	-	-	1	5	7	36

Fig. 8 – Additional information - EN50160

There were no observed influences of PVS on the voltage level on at the CCP. Values obtained were below corresponding to the SR EN 50160.

Analysis of the influence on the power factor

Processing and analyzing the recorded data, the medium power factor evolution on all 3 phases are presented in the Figure 9, and for a better representation phase T is shown in Figure 10, for one day.

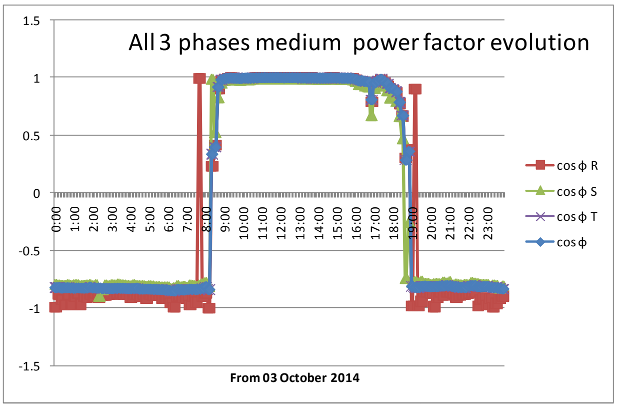

Fig. 9 – Additional information - EN50160

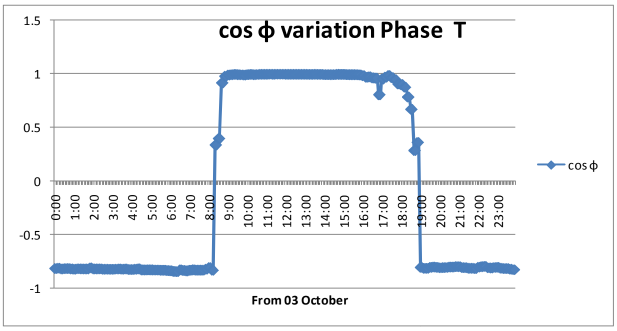

Fig. 10 – Additional information - EN50160

With reference to the power factor, it was concluded the positive contribution of the PVS by injecting reactive power during the operation time (~7.30 ÷ ~19.15). However, at the connection - disconnection moment it has noted an oscillation of power factor the plant. To identify the exact nature of these oscillations some more investigations are required.

Analysis of the influence on the Flicker

As it was presented in the previous chapter, Flicker is considered one of the most significant effects caused by voltage fluctuation.

The measurement results on the Flicker effect was generated directly by the used device as a graphical time evolution report, and regarding the period 3 – 15 October, the result is presented in Figure 11. There were observed some exceeding values of Flicker ($P_{LT} \leq 1$ - standard EN 50160). Higher values can be observed, above the threshold with their duration.

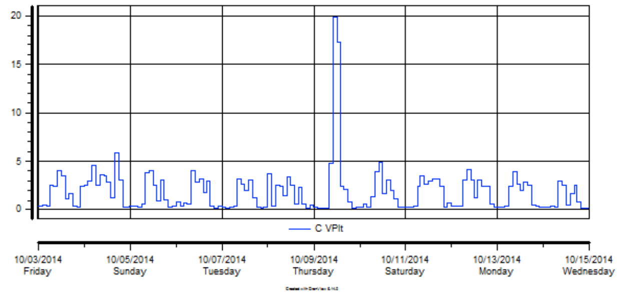

Fig. 11 – Flicker level of variation (3÷15 Oct)

With the extracted data from the device database, after further processing the data regarding Flicker values from 0-10, was represented as a frequency histogram, in the Figure 12.

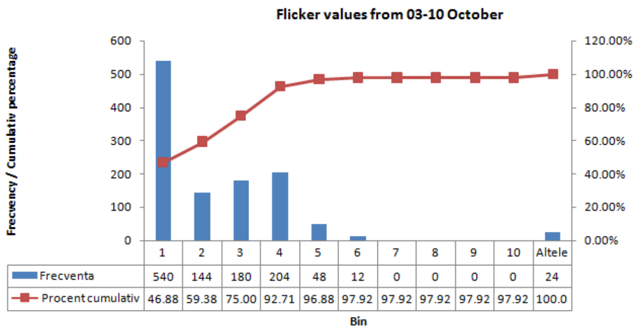

Fig. 12 – Flicker values (3÷15 Oct)

Since the level of long term Flicker for a period of a week must be under the one unit, at least 95%, from the obtained results can be observed that this limit is exceeded in case of the considered PVS. Only 46% of the 1152 values are ≤ 1, and 53.12% is above 1.

Due to high levels of high Flicker found, future investigations will be made to identify the cause, but already there are some indications that the nearby power station has a weight in this problem.

4. CONCLUSIONS

After analyzing the impact of PVS on the voltage at the CCP, it is found that these values correspond to the prescriptions SR EN 50160.

Analyzing the impact of the considered PVS upon the power factor in CCP, we found that the values correspond to the actual requirements of ANRE Order 30/2013.

Given the standard EN 50160, which clearly defines that the severity of long lasting Flicker must have values ≤ 1 [ru] on an interval at least 95% of a week, analysis confirmed that in case of analyzed PVS this threshold has been exceeded. At this moment we can't impute entirely to the presence of PVS.

5. REFERENCES

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