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ISSUES OF ELECTROMAGNETIC COMPATIBILITY IN PHOTOVOLTAIC POWER PLANTS

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Abstract: Electromagnetic energy conversion plants produce electric and magnetic fields which, depending on certain parameters, can affect human or other living organisms. Appeared more and more often and to increasing capacities, due to ecological conditions, the energy potential of the sun, energy efficiency and the easy way of producing electricity, in the photovoltaic power plantsis is stared to become the problem of electromagnetic compatibility with both the installations of neighboring utilities, as technical systems as well as with the biological environment. Thus, in the paper through theoretical analyzes and practical measurements of the electromagnetic field sizes, the authors address some problems of electromagnetic compatibility existing in the photovoltaic power plants on a chosen case study of reference.
Keywords: electromagnetic field, photovoltaic power plants(PVP)

1. INTRODUCTION

Photovoltaic power plants are utilities that convert solar radiation into electricity. In addition to these, solar power utilities also include thermal plants. Solar thermal power plants convert solar radiation into heat. The heat thus obtained is used directly in air conditioning installations, heating domestic water, creating the steam needed for various technological processes, or using thermodynamic cycles to heat a working agent for the turbine of an electric generator.

Direct conversion of solar energy into electricity based on the photovoltaic effect is one of my most attractive means of using solar energy, due to - among others - the limitation by the thermodynamic cycles, the high values of the specific power produced (per unit mass and unit. area), safety in operation and easy maintenance[4]. Photovoltaic solar power plants are made of photovoltaic panels. Photovoltaic panels are composed of photovoltaic solar cells (the smallest unit) grouped into modules.

The block diagram of a photovoltaic power plant (PVP) is shown in figure 1.

From the block diagram it can be seen that a photovoltaic power plant is composed of the following parts:

- solar panels and radiation concentrators;
- inverter, for obtaining the alternating current from the continuous one produced by the photovoltaic effect;
- batteries (accumulators) used for the accumulation of direct current energy (for storing the energy produced);
- battery charging controller (protects the battery / battery from overcharging or overloading);
- components of electrical nature for the distribution of electricity, for the protection and the regulation of the evacuated power etc.

The connection to the Power System(PWS) is made through the medium voltage transformer substations.

2. ELECTROMAGNETIC DISTURBANCES GENERATED BY PVP

Electromagnetic compatibility (EMC) means the coexistence in good conditions of all sources and receivers in the electromagnetic environment.[6][7]. By electromagnetic "compatibilization" is meant the action of adopting the methods and means necessary for achieving electromagnetic compatibility [8]. An electrical device is considered compatible if as a transmitter it produces tolerable emissions and as a receiver it has an acceptable susceptibility to disruptive emissions that is to say it has resistance to disturbances, respectively sufficient immunity. The installations for the production, transport, distribution and use of electricity require the harmonious cohabitation of strong current electromagnetic systems with the low current electromagnetic systems necessary for the measurement, protection, automation, data acquisition and processing and operational management of energy systems [1].

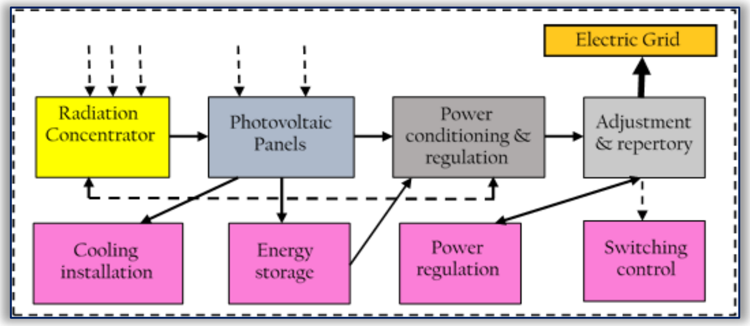


Figure 1 - Block diagram of a photovoltaic power plant

Following the block diagram of figure 1, one can appreciate the way of producing and transmitting the electromagnetic fields by a photovoltaic power plant. Thus in accordance with the physical reality and the principles of electromagnetic compatibility the disturbances are transmitted by conductive coupling mechanisms, radiation, convective, simple or combination, being of the next forms [7][8]: non-sinusoidal or asymmetric voltages and currents, voltage gaps , transient and transient over-voltages, fast and slow voltage fluctuations, voltage and current harmonics, magnetic and electric induction quantified by field intensity or electromagnetic power density transmitted. In photovoltaic power plants, the generation of the electromagnetic field is done on the sectors formed by the DC and the alternative current part, based on which the scheme of figure 2 was drawn. The figure is not shows the secondary circuits that contribute to the permanent monitoring of the energy parameters, protection and automation.

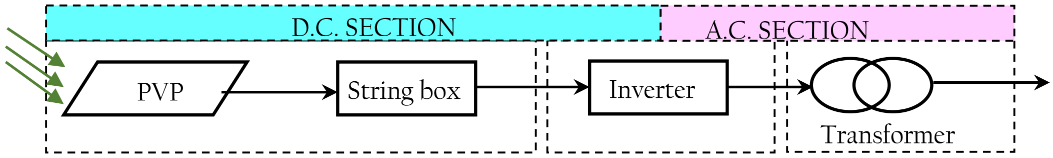


Figure 2 - Scheme of PVP with limits between direct current and alternative current components

3. SOLAR PHOTOVOLTAIC POTENTIAL OF BIHOR COUNTY

According to the value of the intensity of solar radiation in Romania, the country territory is divided into five zones numbered from I to V, as it appears in the profile maps in the specialized literature [4]. The County of Bihor has in the western part an area extended throughout the north-south alignment, which is included in the area of solar radiation II (1300 - 1350 kWh / m^2 / year). In the middle region, extended from north to south there is the radiation zone III (1250-1300 kWh / m^2 / year). In the south-east part of the county, in the area of the Apuseni Mountains, the IV and V solar radiation zones predominate, with low intensities (1200-1250 for IV zone and below 1200 kWh / m^2 / year for V zone) of the distribution of solar power plants on the territory of Bihor county for the end of 2013 is shown in figure 3 according to data from [5].

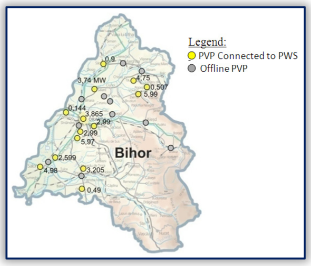


Figure 3 – A situation of PVP in Bihor County

The dynamics of photovoltaic power plants development is quite accentuated because, at the level of Bihor County, until the end of 2014, a number of 47 sites were authorized to operate, with an increase of 22 units compared to 2012. They are connected on the voltage level of 20 kV at the power grids of the electricity Company - "Electrica Distribuție Transilvania Nord", managed by the Oradea branch. Their installed power ranges from 10 kW to 9,8 MW. In total, on the whole of the county, the power of photovoltaic power plants is 123,572 MW.

Figure 4 - Electromagnetic field detector

4. PROCEDURE AND RESULTS OF ELECTROMAGNETIC FIELD QUANTITIES MEASURED IN REFERENCE PVP

The measurements made to assess the values of the magnetic induction and the electric field strength and presented in this paragraph had as target the PVP Salonta-Bihor County belonging to the Company Green Tehnic SRL.

As other electrical structures with the increase in power the electromagnetic influences are stronger, both for indoor and neighboring installations [2] [3]. The photovoltaic panels in the structure of the analyzed PVP are made up of modules arranged on four rows, each module having 120 cells with a total power of 25 W. The disturbances transmitted by conduction and radiation were measured. For the part of the disturbances emitted by radiation, a detector with electric and magnetic field probes with variable frequency was used, model CA 42 production Chauvin Arnoux that has the image in figure 4. The device allows both the measurement of the magnetic induction and the electric field strength has deterministic values displayed in the form of numbers but also the variation in time in the form of curves having the function of oscilloscope. The objective was to verify the admissible values of the electromagnetic field sizes according to the recommendations of international norms [9] [10].

The PVP was put into operation in 2014 and has an installed power of about 5 MW (4992 kW) being located at a distance of 1.75 km from the local power station. It consists of 20784 modulated panels each with a total power of 960 W [4]. Each module has 4 separate panels with 240 W unit power the total number of modules amounting to 5122. The panels are mounted on the upper floor and form on the territory of the plant two assembly groups, each having 5 layout lines. The evacuation is done, on the line of 20 kV with double circuits Oradea-Salonta, Salonta

Figure 5 - Images with Salonta PVP: a - for ensemble; b - inside inverter box (conversion unit)

- Cefa and is made with conductor „Ol- Al 3x120 / 21 mm^2. The line connection is made by air type through two poles with conductor type OL-AL 3x50 / 8 mm^2 at a distance of 30 m from the medium voltage power substation.

The components producing electromagnetic field from the power station can be analyzed on voltage levels. The power plant has a total of 20 inverters, manufactured by VACON model RS I20-0460-3 arranged in 5 connection points distributed over its entire surface. The maximum power is 255 kW on the DC side of the panels. The maximum continuous voltage is 911 V, respectively the maximum input current of 561 A. The voltage produced by the panel depending on the solar power varies between 460 - 850 V. The maximum power is 250 kW on the AC side, at a voltage of 320 V. The maximum output current is 460 A. The nominal frequency is 50 Hz. The power factor at rated capacity is 0.99. The maximum efficiency is by 97.6% at 450 V DC. Energy evacuation is done through 5 transformers (T1 ÷ T5) of 1000 kVA, 20 / 0,32 kV levels, connection type of coils is Dy-n1, u_k = 6%. Each output transformer is connected on the low voltage side by 4 branches of the three-phase inverters, with the connection devices and the related protections, by WL type 3x1 CHBU 150 RF.

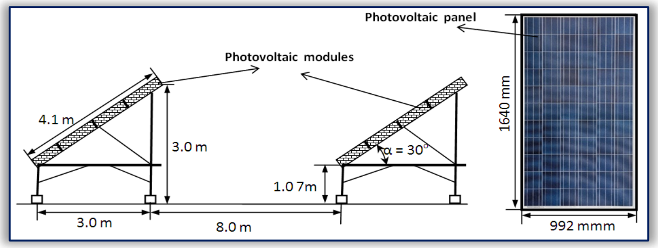


Figure 6 - The emplacement and dimensions of photovoltaic modules and panels

Figure 6 shows the structure and dimensions of photovoltaic modules and panels.

Within the PVP, measurements were made in the vicinity of the photovoltaic panels and inside the energy conversion boxes - in inverter boxes. The perimeter of the external measurements is marked with a blue border in figure 7. For selected area, the measuring routes, are indicated in figure 8(routes 1÷9). The measurement diagram for an outer portion of the considered PVP, with the indication of the access routes is shown in figure 8. For each panel measurements were made on the front, exposed to the sun and the back, where the connections for the energy evacuation are made. The lengths of the outer routes are 16 m on the side of the panels and 60 m along them. In the case of conversion units, measurements were made at the central point of their interior. The height of measurement is 1.7 m.

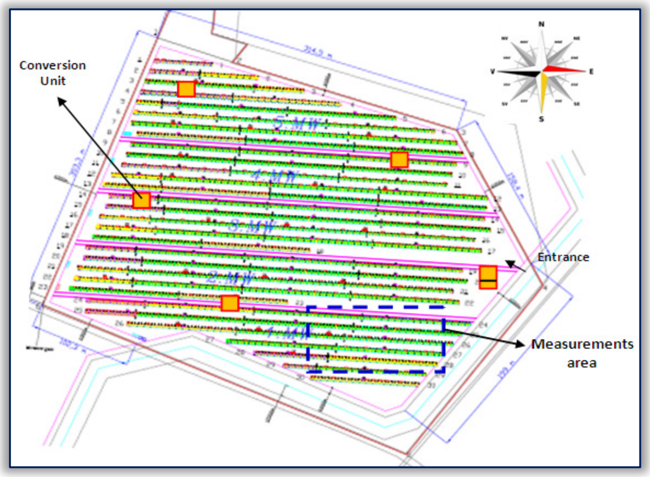


Figure 7 - Scheme of placement of photovoltaic panels in Salonta PVP

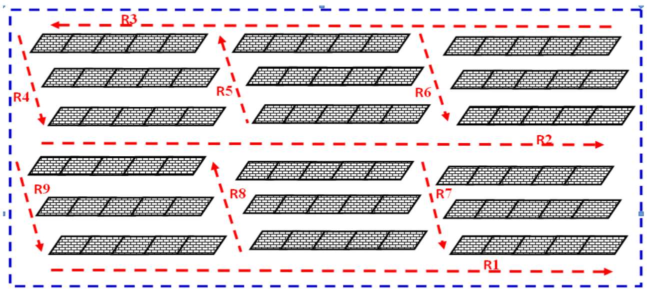


Figure 8 - Measurement scheme for a PVP sector with the highlighting of the routes

The measurement step Δs, is 2 m, resulting in a number of 9 measurement points for the lateral sides, respectively 31 points for the longitudinal sides. The maximum and average values of the electromagnetic field quantities resulted from measurements for the conversion units, are presented in table 1, with the letter "p" which indicated the measurement points.

Table 1- The values of the electric field strength and the magnetic induction measured inside the Salonta PVP conversion units

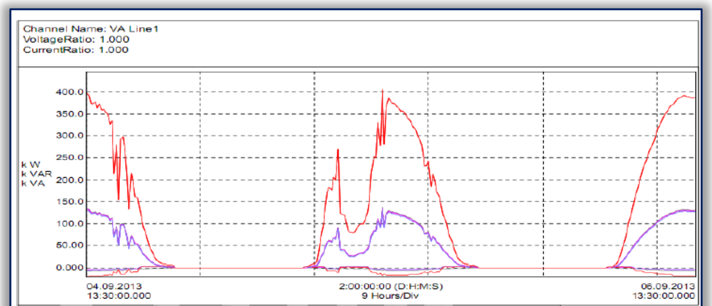
Values of electromagnetic field quantities E_{max}/E_{med}[V/m]; B_{max}/B_{med}[μT]									
P1	26/12	P2	22/15	P3	26/11	P4	32/12	P5	34/10
	0,12/0,09		0,23/0,11		0,34/0,12		0,35/0,14		0,22/0,11

Table 2 - The values of the electric field strength and the magnetic induction for the external measurement routes belonging to Salonta PVP

Values of B[μT]	Values of magnetic induction on measuring routes								
	Route 1	Route 2	Route 3	Route 4	Route 5	Route 6	Route 7	Route 8	Route 9
B_{max}	1,123	0,984	1,123	0,984	1,123	0,984	1,123	0,984	1,123
B_{med}	0,352	0.224	0,352	0.224	0,352	0.224	0,352	0.224	0,352
Values of E[V/m]	Values of electric field strenght on measuring routes								
	Route1	Route 2	Route 3	Route 4	Route 5	Route 6	Route 7	Route 8	Route 9
E_{max}	120	110	140	86	120	110	140	86	95
E_{med}	90	68	102	24	90	68	102	24	54

In the case of the external routes established on the territory of the PVP, according to the markings in figure 7, the maximum and average values obtained are shown in table 2. For the part of the disturbances transmitted by the conduction, it is presented in figure 9, from the same power station according to the results from [4], the values of the exhausted powers are in the form of load curves obtained with an energy analyzer.

Analyzing the time variations of the quantities from figure 9, it can be seen that they have a deformed character having significant sinusoidal curve fluctuations that can cause disturbances in the sensitive circuits of low currents with those of telecommunications. It is necessary to take measures of electromagnetic compatibility by using harmonic filters [8]. For the continuous current part, the measured values fall below the permissible limits as noted in [1] [3].



Name	Date	Time	Avg	Min	Max	Units
VA Line1	04.09.2013	13:30:00.000	37.026k	0.0000	137.12k	VA
VA Line2	04.09.2013	13:30:00.000	36.790k	0.0000	135.42k	VA
VA Line3	04.09.2013	13:30:00.000	35.810k	0.0000	133.05k	VA
VA Sum of Phases	04.09.2013	13:30:00.000	109.63k	0.0000	405.59k	VA
VAR Line1	04.09.2013	13:30:00.000	-2.3933k	-7.9352k	0.0000	VAR
VAR Line2	04.09.2013	13:30:00.000	-833.49	-5.6961k	2.5287k	VAR
VAR Line3	04.09.2013	13:30:00.000	-793.79	-5.9653k	2.9019k	VAR
VAR Sum of Phases	04.09.2013	13:30:00.000	-4.0206	-19.573	4.3643	k VAR
W Line1	04.09.2013	13:30:00.000	36.894k	-192.51	136.89k	W
W Line2	04.09.2013	13:30:00.000	36.691k	0.0000	135.31k	W
W Line3	04.09.2013	13:30:00.000	35.578	-1.0876	132.93	k W
W Sum of Phases	04.09.2013	13:30:00.000	109.16k	-972.15	405.13k	W

Figure 9 – Time-varying of loads at inverter

5. CONCLUSIONS

If the largest photovoltaic power plants were initially located on agricultural fields or other similar land, they are now largely located on buildings. These buildings are located in urban agglomerations. In these situations, the electromagnetic damage of the own and neighboring installations as well as of the health is a problem that has to be intensively investigated. Only the comparison of the parameters with those considered dangerous and the laboratory testing of the effects of the long-term exposure can have conclusive results.

The electromagnetic fields in the power station contribute primarily to the operation of the solar panels by generating the photovoltaic effect. Then the discharge of electricity at high powers also requires high values of the parameters of the electromagnetic field. The areas with intense fields should be avoided by the operating personnel or the general population. The automation of energy processes and the remote monitoring of installations can be a solution to highlight dangerous exposures.

Measures for filtering and compensating for deviations must be applied for the electrical quantities that damage the quality of the electricity producing disturbances.

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