Electric and Magnetic Fields due to Rooftop Photovoltaic Units

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Abstract- **This paper investigates the electric and magnetic fields created due to the operation of roof-mounted photovoltaic units. For this purpose the most recent reference levels for safe general public and occupational exposure given in the guidelines of the International Commission on Non-Ionizing Radiation Protection are first presented. Basic constructional and operational data of the rooftop photovoltaic installations are examined follow, as well as a description of the measurement process. Electric and magnetic field measurements in typical photovoltaic units with different nominal powers and inverter types (single or three-phase) are performed under convenient weather conditions that ensure maximum electricity production. The main measurement results are evaluated according to the reference levels for safe public exposure, and the conclusion finally derived is that the examined fields are not dangerous and, therefore, are no cause for concern among the public.**

Keywords- Electric and Magnetic Field Measurements; Reference Levels; Rooftop Photovoltaic Units; Safe Public Exposure

I. INTRODUCTION

Exposure to man-made electric and magnetic fields has been steadily increasing over the last century. The benefits of using electricity in everyday life and healthcare are unquestioned, but during the last few years members of the scientific community as well as the general public have become increasingly concerned about the potential health hazards of exposure to electric and magnetic fields (EMFs) at extremely low frequencies (ELF).

These fields have been suspected of causing or contributing to adverse health effects. Although some health effects have been statistically related to ELF EMF exposure, these effects are poorly understood and may only exist as statistical or scientific errors. The final conclusion of the relevant work done by several expert working groups all over the world is that more research is required in order to provide an accurate answer to the question “do ELF EMFs present a human health hazard?”

Nowadays, national standards as well as generally accepted guidelines define reference levels for safe public and occupational exposure to ELF EMFs. Specifically, according to the most recently updated International Commission on Non-Ionizing Radiation Protection (ICNIRP) [1] guidelines, these levels for safe general public exposure and for a frequency of 50 Hz are:

- For electric field strength, $E < 5$ kV m^{-1}
- For magnetic field strength, $H < 100$ A/m
- For magnetic flux density, $B < 200$ μT

The relevant levels for safe occupational exposure are:

- For electric field strength, $E < 10$ kV m^{-1}
- For magnetic field strength, $H < 800$ A/m
- For magnetic flux density, $B < 1000$ μT

ICNIRP’s limiting thresholds for general public exposure are widely accepted as providing complete protection against all known adverse health effects of EMFs. Indeed so do the occupational levels, which allow for a higher exposure for trained workers, the difference being the provision of a greater safety margin for the general public.

People find it difficult to reconcile the ICNIRP reference level of 200 μT with findings from some epidemiological research showing an apparent correlation between an approximate doubling in the very low risk of childhood leukemia and long-term exposure to average fields greater than 0.4 μT. ICNIRP considered the epidemiological data suggesting possible associations with childhood leukemia when preparing their guidelines, and have reviewed the data several times since then. While ICNIRP recognises the association, they do not consider that a risk has been established. Rather there is a possibility that there might be a very low risk.

Various researchers have extensively treated the EMFs generated by transmission lines [2, 3], power stations and substations [4-9] of various voltage levels, domestic appliances [10, 11], etc. Limited data are available for the fields of photovoltaic (PV) units. In particular, the report [12] documents the data and compares the PV magnetic fields with published data on more prevalent magnetic field sources. The conclusions are that 60-Hz magnetic fields (the EMF type of greatest public concern) are significantly less for PV arrays than for household applications. Therefore, PV array EMF may not merit considerable concern. The PV system components exhibiting significant AC magnetic fields are the transformers and power conditioning units. However, the AC magnetic fields associated with these components are localized and are not detected at PV system perimeters.The authors of [13] give magnetic field measurements on an alternating current PV module with an attached inverter, while the authors of [14] give sound pressure levels and EMF measurements at three utility-scale sites with solar PV arrays as well as at one residential PV installation, but only from inside the house. The measured field values in these papers are far below the safe exposure levels, according to the conclusions given by the authors.

In Greece, during the last few years a huge number of independent producer applications have been submitted and approved, concerning ground and roof-mounted photovoltaic (PV) systems connected to the power distribution network. The Greek Government subsidises the production of these 'green' kWhs in order to meet the environmental constraints established by the Kyoto Protocol and other governmental initiatives primarily concerning fuel saving. This paper investigates the EMFs created due to the operation of rooftop PV units. The close proximity of these units to houses and workplaces causes anxiety amongst people over the possible health hazards from the resultant EMFs. Therefore, first of all the basic constructional and operational data of these installations are provided. EMF measurements in typical roof-mounted PV systems with different nominal powers and inverter types (single or three-phase) have been undertaken. The main measurement results have been evaluated according to the ICNIRP guidelines. Conclusions, concerning safe public exposure to these fields have been finally derived.

II. ROOFTOP PV UNITS AND EMF MEASUREMENTS

The EMF measurements were performed in PV systems mounted on the roofs of three residences in the region of Xanthi, Greece, which corresponds to latitude of 41^{o}. These residences are denoted below with the letters A, B and C. Indicative measurements were initially taken for different weather conditions, which affect the output of the PV units. In this paper the measurements performed on 4th March 2013, between 10:30 am and 14:00 pm, under clear sky conditions and with an ambient temperature around 12^{o}C are given. The above-mentioned ambient conditions provided a very good performance of the PV units.

The instrument used for the EMF measurements was the EFA – 3 analysers, constructed by the Wandel & Goltermann Company, which is only able to take AC field measurements at a frequency range from 5 Hz to 30 kHz. The same instrument was used in [4], where its characteristics are given in detail.

The PV facilities selected for examination have different nominal powers and inverter types, in order to estimate the possible effect of these parameters on the EMF values. This paper does not examine PV units with solar panels of different technologies (polycrystalline silicon, monocrystalline silicon, building integrated photovoltaics, etc.), since the most common technology used for roof PV units is polycrystalline silicon panels which are less expensive. In particular, the PV unit mounted on the roof of residence A has a nominal power of 8.05 kW, it consists of 35 polycrystalline silicon solar panels, with a nominal power of 230 W each and is connected to the distribution network via three single-phase inverters, each equipped with a high frequency isolation transformer, also located on the roof of the residence. This transformer provides filtering so that a pure sine wave is generated at the inverter's alternating current (AC) output, which permits stepping-up of the voltage to match the grid's voltage for a given input direct current (DC) voltage and decouples the DC system from the AC system so that each system's ground is not coupled through the source circuits. The PV unit of residence B has a nominal power of 4.8 kW; it consists of 20 polycrystalline silicon solar panels with a nominal power of 240 W each and is connected to the distribution network via one single-phase inverter outside the roof. Finally, the PV unit of residence C has a nominal power of 9.84 kW; it consists of 41 polycrystalline silicon solar panels with a nominal power of 240 W each and is connected to the distribution network via one three-phase inverter outside the roof.

The initial intention was to take magnetic field measurements every 2 m (horizontally and vertically), within the range of frequencies and for three different heights (measured above the roof surface): head height (2 m), waist height (1 m) and roof surface (0 m). Indicative measurements carried out showed that the 50 Hz component is dominant, making the harmonic components negligible.

The measurement process for residence A is described in detail below. Fig. 1 provides a photo view of the roof of residence A, while Fig. 2 shows the ground plan of this roof with the positions scheduled to obtain EMF measurements. As shown, three additional positions (A44, A45 and A46) are identified in touch with the inverters, for more detailed measurements, apart from the basic measurement positions (A0–A43). Table 1 shows the measured magnetic flux density values (rms values in μT) on the roof of residence A. The measured values are below the reference level for safe public exposure, which is equal to 200 μT, for all measurement positions and for all heights. In the majority of these positions the magnetic flux density value is extremely low. Specifically, it does not exceed the value of 1 μT whilst the maximum magnetic flux density value was measured at the location of the inverters and was equal to 118 μT. The isolation transformers of these inverters are an additional reason for the increased magnetic flux density value in this case. Only in four positions and for a height of 2 m was it impossible to take field measurements due to the existence of solar panels. No serious differentiation was noted in the measured magnetic flux density values in relation to height, as Table 1 shows. As a consequence, the only measurements performed thereafter in residences B and C correspond to a height of 1 m.

Fig. 1 Photo view of the roof of residence A

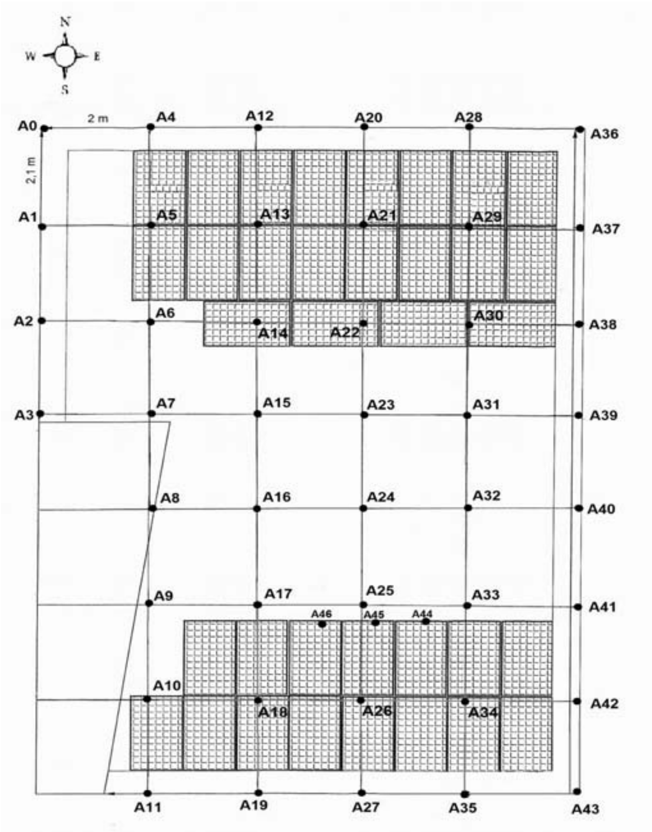

Fig. 2 Ground plan of the roof of residence A showing measurement positions

Magnetic field measurements were also performed in many other locations around the residence where its residents perform activities, but the resulting values were negligible.

During the measurement process in residence A, the power of the PV unit was equal to 6.4 kW which is very close to its nominal power (maximum electricity produced).

The measurement process described above for residence A was also followed by residences B and C. All the measured magnetic flux density values in these residences were also far below the reference level for safe public exposure. In particular, in residence B the measured values at the grid positions on the roof were between 0.32 μT and 0.52 μT, whilst the maximum magnetic flux density value was measured at the inverter position, outside the roof and it was equal to 24 μT. In residence C, the measured values at the grid positions on the roof were between 0.32 μT and 1.2 μT, whilst the maximum magnetic flux density value was also measured at the inverter position, outside the roof and it was equal to 12 μT. The measured magnetic flux density values in many other positions inside residences B and C were negligible. During the measurement process in residences B and C, the power of the PV units was 4.6 kW and 8.4 kW, respectively (also very close to their nominal power).

TABLE 1 MAGNETIC FLUX DENSITY VALUES IN THE PV UNIT OF RESIDENCE A

	Magnetic flux density values *B* (μT)		
Measurement position	**Height 0m**	**Height 1m**	**Height 2m**
A0	0.37	0.30	0.33
A1	0.32	0.38	0.38
A2	0.37	0.33	0.33
A3	7.00	0.31	0.35
A4	0.36	0.30	0.33
A5	0.36	0.36	-
A6	0.43	0.32	0.52
A7	0.35	0.37	0.38
A8	0.44	0.30	0.35
A9	0.30	0.34	0.34
A10	0.35	0.36	0.34
A11	0.35	0.36	0.34
A12	0.32	0.35	0.38
A13	0.36	0.38	-
A14	0.35	0.36	0.41
A15	0.35	0.37	0.35
A16	0.44	0.30	0.35
A17	0.40	0.32	0.34
A18	0.35	0.36	0.34
A19	0.35	0.36	0.34
A20	0.29	0.28	0.39
A21	0.37	0.32	-
A22	0.47	0.49	0.33
A23	0.43	0.39	0.41
A24	0.44	0.30	0.35
A25	0.44	4.20	1.80
A26	0.35	0.36	0.34
A27	0.35	0.36	0.34
A28	0.30	0.33	0.36
A29	0.33	0.34	-
A30	0.45	0.33	0.37
A31	0.43	0.32	0.41
A32	0.44	0.30	0.35
A33	0.35	3.50	0.45
A34	0.35	0.36	0.34
A35	0.35	0.36	0.34
A36	0.41	0.29	0.28
A37	0.37	0.31	0.30
A38	0.30	0.33	0.36
A39	0.43	0.32	0.41
A40	0.53	0.55	0.33
A41	0.64	0.66	0.38
A42	0.35	0.36	0.34
A43	0.35	0.36	0.34
A44	0.34	118.00	0.85
A45	0.34	113.00	0.85
A46	0.34	108.00	0.85

As mentioned above, during the measurement process all three PV examined units were operating close to – but lower than – their nominal power. However, even if the measured magnetic flux density values were extrapolated to the nominal power of the PV units, the resulting values would also remain far below the relevant reference level for safe public exposure.

Concerning the electric field strength measurements, the electric field sensor was placed on a tripod at the height of 1.7 m, at several roof positions at each residence and it was connected to the main instrument with a 10m fibre optic cable. This connection and the distance between the sensor and the main instrument were necessary in order to ensure that the electric field strength would not be perturbed by human presence. In none of the residences was it necessary to perform the total number of scheduled electric field strength measurements, because indicative measurements that were taken showed that the electric field strength did not differentiate significantly with the measurement position. The measured electric field strength values in all the residences were extremely lower than the reference level for safe public exposure, which is equal to 5 kV/m. Specifically, in residence A the entire electric field strength values were around 2 V/m, except for one point, where a distribution cable passes and this value was equal to 28.9 V/m. In residence B the entire measured electric field strength values were between 22 and 36 V/m. In this case the electric field was relatively higher due to a low voltage distribution network existing very close to the residence. The measured values at the inverter position were very low. In residence C the entire measured electric field strength values were between 2.2 and 3 V/m, while at the inverter position 2 V/m were measured. Electric field measurements were also performed in many other places around the residences, but the resulting values were negligible.

III. CONCLUSIONS

In recent years, the general public and working personnel have become increasingly concerned about the health hazards of exposure to ELF EMFs. National and international guidelines have enacted reference levels for safe exposure, while researchers from different areas of expertise deal with the above-mentioned health effects.

This paper reports the results of EMF measurements due to rooftop PV installations which have different nominal powers and inverter types. The measurements have been performed in order to determine whether the internationally accepted reference levels for safe public exposure are violated. Both these measurements and the elaboration of the relevant results showed that the magnitudes of the measured field values are within recognised guidelines, suggesting that these fields are not dangerous and, therefore, are no cause for concern among the public.

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