Influences of High Relative Humidity on Extremely Low Frequency Electric Field Measurements

Leena Korpinen[1], **Hiroo Tarao**[1,2], **Rauno Pääkkönen**[1], **Oleksandr Okun**[3,4], **and Lauri Sydänheimo**[1]

[1]Tampere University of Technology, Tampere, Finland
[2]Department of Electrical and Computer Engineering
Kagawa National College of Technology, Kagawa, Japan
[3]LLC Soyuzenergoproekt, Kharkiv, Ukraine
[4]Department of Electrical Energy
National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine

Abstract— The paper presents a study of extremely low frequency (ELF) electric field (EF) measurements in a climate room when the electric field meters were in a high-humidity environment before the measurements. We employed two methods: (1) the sensor was placed on a tripod; and (2) the sensor was fixed using a plastic clamp and was suspended by three fishing lines. We evaluated only two sensor types. However, we noted that a high-humidity environment before the measurement period influenced the results. In the future, it is important to take pre-measurement humidity into account.

1. INTRODUCTION

An earlier study [3, 4] indicated that humidity can influence electric field measurement results; thus, it is important to take into account when these results will be compared to the values given in different exposure safety guidelines (e.g., the International Commission on Non-Ionizing Radiation Protection (ICNIRP) [2] or Directive 2013/35/EU of the European Parliament and of the Council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) [1].

The aim of the study was to investigate extremely low frequency (ELF) electric field measurements in a climate room when the electric field meters were in a high-humidity environment before the measurements.

2. MATERIALS AND METHODS

We used the commercial three-axis meters EFA-3 and EFA-300, which contained a bandwidth ranging from 5 Hz to 2 kHz. We employed two methods: (1) the sensor was placed on a tripod (Fig. 1.); and (2) the sensor was fixed using a plastic clamp and was suspended by three fishing lines (Fig. 2).

Figure 1: Method 1 — the sensor placed on tripod.

Figure 2: Method 2 — sensor fixed using plastic clamp and three fishing lines.

With Method 1 (with both meters), the first experiment period included 7 measurements, when the relative humidity was 75%, the temperature was 15°C and the electric fields varied from 1 kV/m to 25 kV/m. Then, the meter measurements took over 3 hours, exposing them to humidity varying from 79% to 95%. Then, the second measurement period began. With Method 2, the protocol was similar; however, the meters endured high humidity for over 5 hours and temperature varied.

3. RESULTS AND DISCUSSION

Tables 1–8 show the measured results with Methods 1 and 2 using two meters EFA-3 and EFA-300.

Table 1: Measured results with Method 1 (first period) using meter EFA-3 (planed relative humidity 75% and planed temperature 15°C).

Measured temperature°C	Relative humidity, %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/,m	Error $(E_m - E)/E\%$
15.3	75.1	0.78	1.04	1.06	1.6
15.4	74.8	3.81	5.08	5.24	3
15.4	74.7	5.25	7	7.23	3.3
15.4	74.6	7.58	10.11	10.41	3
15.5	74.6	11.22	14.96	15.36	2.7
15.5	74.4	15.05	20.07	20.63	2.8
15.5	74.3	18.73	24.97	25.69	2.9

Table 2: Measured results with Method 1 (second period) using meter EFA-3 (planed relative humidity 75% and planed temperature 15–25°C).

Measured temperature°C	Relative humidity, %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/,m	Error $(E_m - E)/E$ %
25	74.9	0.76	1.013	1.08	6.8
25	75.4	3.66	4.88	5.4	10.6
25	75.4	5.21	6.95	7.69	10.7
24.9	75.5	7.45	9.93	11.2	12.8
24.8	75.8	11.33	15.11	17.12	13.3
24.8	76.1	15.06	20.08	22.93	14.2
24.7	76.2	18.76	25.01	28.65	14.5
19.4	79.7	0.77	1.03	1.06	3.6
19.5	79.4	3.77	5.03	5.44	8.3
19.6	79.1	5.22	6.96	7.62	9.4
19.6	78.9	7.54	10.05	10.95	8.9
19.6	78.7	11.26	15.01	16.45	9.6
19.6	78.6	15.09	20.12	22.23	10.5
19.7	78.6	18.83	25.11	27.81	10.8
19.8	74	0.77	1.03	1.02	−1.1
19.7	74.6	3.72	4.96	5.05	1.8
19.7	74.7	5.22	6.96	7.11	2.2
19.7	74.7	7.47	9.96	10.29	3.4
19.7	74.4	11.27	15.03	15.57	3.6
19.7	74.2	15.01	20.01	20.77	3.8
19.7	74.3	18.77	25.03	26.05	4.1
14.7	75.7	0.77	1.03	1.02	−1
14.6	76	3.74	4.99	5.01	0.4
14.6	76.2	5.25	7	7.1	1.5
14.6	76	7.49	9.99	10.22	2.3
14.7	75.8	11.31	15.08	15.35	1.8
14.8	75.6	14.89	19.85	20.29	2.2

In the first periods of Method 1, the maximum percentage error was 5.6%, and in Method 2, it was 11.9%. In the second period, the maximum percentage errors were 14.5% (Method 1) and 24.4% (Method 2).

Table 3: Measured results with Method 2 (first period) using meter EFA-3 (planed relative humidity 75% and planed temperature 15°C).

Measured temperature°C	Relative humidity, %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/,m	Error $(E_m - E)/E$ %
15	75.2	0.78	1.04	1.16	11.9
14.9	75.4	3.78	5.04	5.6	11.2
14.9	75.3	5.24	6.99	7.78	11.3
15	75.3	7.43	9.91	11.01	11.1
15	75.2	11.33	15.11	16.67	10.4
15.1	74.9	14.96	19.95	21.8	9.3
15.1	74.9	18.8	25.07	27.2	8.5

Table 4: Measured results with Method 2 (second period) using meter EFA-3 (planed relative humidity 75% and planed temperature 25°C).

Measured temperature°C	Relative humidity, %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/,m	Error $(E_m - E)/E$ %
25	74.7	0.78	1.04	1.27	22.5
25.1	74.8	3.65	4.87	6.05	24.4
25	75	5.21	6.95	8.59	23.7
25	75	7.45	9.93	12.27	23.5
24.9	74.9	11.25	15	18.38	22.5
24.8	75.4	14.97	19.96	24.43	22.4
24.8	75.4	18.71	24.95	30.5	22.2

Table 5: Measured results with Method 1 (first period) using meter EFA-300 (planed relative humidity 75% and planed temperature 15°C).

Measured temperature°C	Relative humidity, %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/,m	Error $(E_m - E)/E$ %
14.7	74.5	0.76	1.01	1.07	5.6
14.7	74.2	3.73	4.97	5.18	4.2
14.8	74.1	5.24	6.99	7.32	4.8
14.8	74.1	7.49	9.99	10.46	4.7
14.8	74	11.22	14.96	15.69	4.9
14.9	74.1	15.02	20.03	21	4.9
14.9	74.1	18.74	24.99	26.18	4.8

Table 6: Measured results with Method 1 (second period) using meter EFA-300 (planed relative humidity 75% and planed temperature 25°C).

Measured temperature°C	Relative humidity %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/m	Error $(E_m - E)/E$ %
25	74.9	9.76	1.01	0.98	−2.9
24.9	75.1	3.77	5.03	5.06	0.7
24.9	74.9	5.22	6.96	7.1	2.1
24.9	75.4	7.54	10.05	10.18	1.3
24.9	75.3	11.25	15	15.26	1.7
24.9	75.5	14.99	19.99	20.38	2
24.8	75.1	18.75	25	25.55	2.2

The error was always positive in our tests (0–25%), and this means that when the meters give higher values than calculated values, then the relative humidity is high. There are inaccuracies in our tests, but it is also interesting to note that the accuracy of the meters is reported to be ±3–±5%. When the relative humidity is high, it can influence measurement results such that scores fall below the reported accuracy range of the meters. In practice, it is also good to calculate the electric field exposure, when possible, and compare the measurement results to the calculation results.

Table 7: Measured results with Method 2 (first period) using meter EFA-300 (planed relative humidity 75% and planed temperature 15°C).

Measured temperature°C	Relative humidity %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/m	Error $(E_m - E)/E$ %
15	75.4	0.76	1.01	1.1	8.1
15.1	75.6	3.75	5	5.43	8.7
15.1	75.6	5.26	7.01	7.67	9.4
15.1	75.7	7.49	9.99	10.93	9.4
15.1	75.6	11.23	14.97	16.33	9.1
15.1	75.6	14.97	19.96	21.76	9
15.2	75.5	18.75	25	27.2	8.8

Table 8: Measured results with Method 2 (second period) using meter EFA-300 (planed relative humidity 75% and planed temperature 25°C).

Measured temperature°C	Relative humidity %	Voltage, kV	Calculated EF, kV/m	Measured EF, kV/m	Error $(E_m - E)/E$ %
25	75	0.75	1	1.05	5
25	75	3.77	5.03	5.25	4.5
25	75	5.22	6.96	7.37	5.8
25	75	7.54	10.05	10.87	8.1
25	75	11.26	15.01	15.99	6.5
25	75.1	14.98	19.97	21.3	6.6
25	75.1	18.78	25.04	26.8	7

4. CONCLUSION

We evaluated only two sensor types because there are a limited number of commercial sensors available for electric field measurements. Therefore, our material is quite limited. In conclusion, it can be stated that in the future, it is important to also take humidity into account in the pre-measurement period and not only during electric field measurements.

ACKNOWLEDGMENT

The assistance of the staff of the Group of Environmental Health, Tampere University of Technology (Markus Wirta and Tero Haapala) is gratefully acknowledged. Special thanks go to Kari Lahti (Tampere University of Technology, Department of Electrical Engineering) for his advice and support on working in the climate room.

REFERENCES

1. European Parliament and Council of the European Union, "Directive 2013/35/EU of the european parliament and of the council on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (Electromagnetic Fields) (20th individual directive within the meaning of article 16(1) of directive 89/391/EEC) and repealing directive 2004/40/EC," 21, Official Journal of the European Union, 2013.
2. ICNIRP, "Guidelines for limiting exposure to time varying electric and magnetic fields (1 Hz–100 kHz)," *Health Phys.*, Vol. 99, 818–836, 2010.
3. Korpinen, L. H., J. Kuisti, H. Tarao, and J. Elovaara, "Influence of relative humidity on analyzing electric field exposure using ELF electric field measurements," *Bioelectromagnetics*, Vol. 34, No. 5, 414–418, 2013.
4. Korpinen, L., H. Kuisti, H. Tarao, R. Pääkkönen, and J. Elovaara, "Comparison of electric field exposure measurement methods under power lines," *Radiation Protection Dosimetry*, Vol. 158, No. 2, 221–223, 2014.