

A Model Concerning the High Voltage Systems Impact on the Environment inside a Romanian Power Substation

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Abstract: - The paper presents a system designed for monitoring the impact of 220 kV and 400 kV high voltage installations over the environment. The electromagnetic pollution produced by high voltage power plants is analyzed. The experimental results correspond to a case study represented by the Iernut substation. The electric and magnetic field using the developed monitoring system is measured. The component elements of the monitoring system and its advantages are also presented in the paper.

Key-Words: - High Voltage Systems, Environment, Romanian Power Station,

1 Introduction

Increased power consumption is a sustainable trend, shown from the beginning of using this form of energy, not having any sign of change it. Contrary, it is expected that the electricity should gradually occupy a larger share, among different forms of energy suitable for all population and economic activities. Simultaneously together with the development of sources of electricity and the increased need for transmission and distribution facilities, growth that will continue as long as the traditional power systems scheme will be best solution both technically and also economically.

Raising the capacity of transmission facilities requests the increase of electrical overhead lines voltage, as well as the number of the lines. Of these two issues arising with environmental influences related to the installation and operation of transmission and distribution of electricity. The main issues considered are: visual pollution, noise pollution due to the corona phenomenon, electromagnetic pollution due to electromagnetic field of low frequency (and induced biological effects), due to electromagnetic field pollution electromagnetic high frequency (disturbance broadcasts of radio and TV), psychological pollution, Ecological pollution (land occupation, the production of ozone etc.).

Some of these issues have a quantifiable method of computing and measurement, others, such as visual, psychological or biological, can not be sufficiently assessed correctly.

For more than 30 years there are concerns that the determination by calculating and measuring the electric field intensity and the magnetic field generated by high voltage equipment as well as the consequences of the electromagnetic fields they

have on the health and protection of persons. Group may be biological effects in two categories:

- Effects immediate or short-term, which are [undeniable](#). Worldwide there is a consensus, which is materialized by defining the permissible limits on exposure of individuals;
- Long-term effects (cancer, reproductive) which is subject to controversy

Among the most important (but not only) international bodies dealing with regulations on permissible limits for electric and magnetic fields are:

- International Commission for protection against radiation non-ionizing - ICNIRP;
- The European normalization in electro - CENELEC;
- Directorate General V of the European Commission.

The first two institutions are the difference between the population and workers in high-voltage equipment, while the third refers only to workers. All these bodies have been proposed rules on permissible limits of intensity electric and magnetic heads for different frequencies. Can not but speak of a consensus on an international level.

This paper presents a system for monitoring the impact of the high voltage of 220 kV and 400 kV installations over the environment.

2. Considerations on the Electromagnetic Pollution Produced by High Voltage Power Plants

Electromagnetic Field generated by the power plants produces on the human beings and plants around, a series of effects, to which it is necessary to take special protection measures. The intensity of electric field and so its side effects increase with the increasing of installations nominal voltage. That is

why especially at installations of high and very high voltage level is necessary to consider very carefully the effects of disturbance and protective measures required.

The side effects of electromagnetic fields to which it is necessary to take action are:

- disturbances broadcasts and radio and television reception;
- audible noise;
- public security and installations and objects to the voltages induced electrostatic and electromagnetic.

The perturbations level radio and TV is determined by the intensity of the field at the surface of conductor century, the question of partial corona discharges.

The corona phenomenon is manifested in the form of autonomous software and incomplete, concentrated around the item under high voltage. The phenomenon is due to deformities of the power curve that makes software as a result of incomplete ionization air around the item under voltage.

The amount of active power losses due to this phenomenon depends on factors found that: insulator type, the type columns, the conductor section, the distance between phases, the distance between the fascicles of conductors forming a conductor stages of factors and variables such as power plant service conditions weather, surface condition of conductors, clamps and fittings, and the degree of pollution insulators. Radio disturbances may occur between 0,5-1,6 MHz and depend on the rate of superficial voltage conductor, the number of conductors and the beam of a phase, the distance the radio to the line and weather conditions. In fine weather, radio disturbances are about 6 dB, and the intense rain increased to 10-30 dB.

Disturbances television show in the frequency bands between 24 and 216 MHz and increase the intensity of rain may reach levels of 40-70dB, especially in the case of an unfavourable mountings the aerial receiver.

Audible noises accompanying corona phenomenon occurring in the frequency band of 16-20 000 Hz and grow quickly to the radius of conductors, the number of conductors in the beam of a phase and atmospheric humidity. The calculated level of intensity of sound varies between 40 and 60 dB depending on the voltage service line, and the number of conductors phase, the weather conditions and the distance they carry out the calculation or measurement.

Increased of the nominal voltage of the power plants, and the short of current networks, has a ninth problem, namely *security and public installations near the front lines of voltages induced*.

Electric field produced by power lines, leads metal objects or isolated, or in vehicles, which can potentially become dangerous when people come in touch with them. Also, the people who are in intense electric fields can produce biological disturbance. The influence of electric field on the human body is a debated issue alive and currently the world, especially with the introduction into service of installations very high voltages. Discussion is wearing around values to be normal for the intensity of the field, so as not to produce biological disturbance of people who are under the influence of this field, and protective measures required for installations in the vicinity of the line. In the case of a human body electrically isolated to earth (fig.1.a.), but located in an electric field, the body that will operate a current IC whose value will depend on the pulse ω , depend on the factor ϵ_0 , and depend of the electric field intensity E and equivalent area, S .

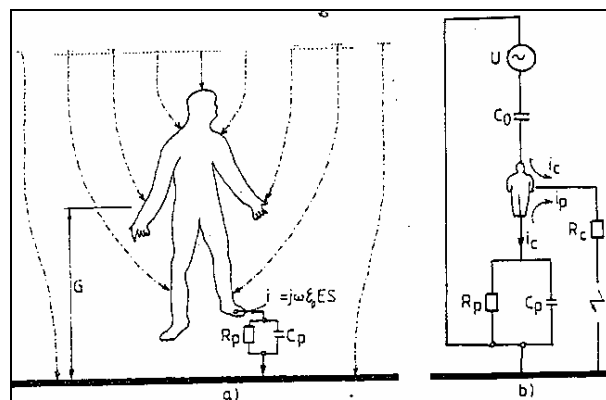


Figure 1. Electricity through the human body due to the electric field
a) man isolated to earth; b) non-isolated man to earth.

The ϵ_0 factor depends on the value of resistance R and the capacitance C . Assuming that the man in question, in the electric field, arrives for some reason in direct contact with the ground, (fig.1.b.), then in parallel with the circuit previously, appear a new circuit in which the human body and which will initially power capacitive current IP and unloading capacity of the human towards the earth. In these conditions electrostatic discharges occur between humans and the element linked to the ground.

The values of the electric field produced by electrical airlines depend by the mainly voltage service line, the distance from the axis line where the measurement of the distance between the conductor under voltage and earth and height over the ground where the measurement is made (in generally 1 m from the ground).

The influences electric field is limited by the maximum permissible values in table 1 and table 2.

Table 1. Maximum allowed values in different countries for the influence of high voltage overhead power lines

Electrical influence	Ex USSR		USA		Canada	Sweden
	A	B	A	B		
Intensity of electric field at ground [kV/m]	20	15	13	7,5	10	11,6
The discharge capacitive current [mA]	4,5	4,5	5	5	-	-
The gradient at the conductor surface [kV/cm]	18	18	-	-	17,5	17,4
The level of audible noise [dB]	-	-	52	52	60	45
The level of radio and television perturbation[dB/ μ V/m]	34	34	37	37	67,5	40-45

A – difficult acces land

B – agricultural land

Table 2. Maximum values recommended in Romania for the influence of electrical field generated by the overhead power lines

The influence of electricity	Value	UM.	Use case
Electric field intensity at 1.8 m above ground	10	kV/m	At crossings of roads, railways and areas of frequent movement
	12	KV/m	In areas with reduced movement
Discharge capacitive current	5	mA	-
The level of radio-TV perturbations	40	dB/(μ V/m)	-
Audible noise	60	dB	Compared to the residential buildings in the vicinity
	50	dB	Compared to the halls of sick or operation rooms in the vicinity
	45	dB	Compared with parks, recreation and rest places in the vicinity

3. The System for Monitoring the Effects of Perturbation of the Electromagnetic Fields Generated by Electrical Installations of High Voltage.

The system is composed of the following equipment and software (table 3).

Electric field is determined by measuring the rate of potential (electric field intensity), in kW / m, with the help of ICEMENERG gradientmeter. It is part of

the measuring apparatus with a floating potential, with detector probe contained in the measure. Probe measuring is a dipole parallel plan and is implemented and therefore form a parallel plates wells isolated from each other according to Standard IEC 833 - *Measurement of electric fields of industrial frequency*. The ICEMENERG gradientmeter, according to Standard IEC 61786/1998 is part of the apparatus of measurement with monoaxial sensor for measuring electric fields exposure on the human body.

Table 3. Equipment used for measurements

Nr crt	Equipment	Produced by	Type	Quantity
1	Device for measuring the electric field	ICEMENERG	Gradientmetru	1
2	Device for measuring the magnetic field	Conrad Electronic	Tesla Monitor	1
3	Laptop	Fujitsu Siemens	Procesor Pentium 4	1
4	Modem PSTN	US Robotics	Courier 56K Bussines	1
5	Data server	Hewlet Packard	Procesor Pentium 4	1
6	Software licence	Power Measurement Canada	ION Enterprise 5.5	1

The magnetic field is determined by measuring the maximum induction B in mT, in the set points, using a device Tesla Monitor. The measure device is a part of the apparatus for measuring the magnetic field with the probe measuring the coil calibrated in a uniform magnetic field created by a solenoid size adequate to ensure uniformity in the field. The measure device complies with the IEC 61786/1998 -

Measurement of electric and magnetic fields exposure on the human body. Special devices for measuring and rules of measurement.

The PSTN modem is a "U.S. Robotics Courier 56K Business dial-up telephone line switched on. Speed of communication is selected 19,200 baud / s. This type of modem settings own store in case of accidental voltage power.

Data server is a personal computer HP Intel P4, 3GHz. Due to high volume of data recorded, for processing in their various forms of statistical capacity storage 1024MB RAM, 120GB HDD Sata. Auxiliary power is provided by UPS. Server database has an LCD monitor 19", a system for printing color multifunctional A4. Communication with Fujitsu Siemens notebook in the system is done by connecting the server to external modem outlined above, the analog telephone circuit.

The operating system is Microsoft Windows NT. Upon request to take data transmitted by portable computer and automatically stored in a database dedicated. The system allows external storage of data transmitted through the built-RW and DVD while securing them. The entire database stored on the server database can be accessed on demand for generating their own programs for data processing primary printing data, graphs, reports. Implementing the system requires making measurements of magnetic fields and substations in the transformation, followed by transmission and storage reports measuring on the central point.

4. Experimental Results

Experimental results from each point of measurement will present:

- schedule normal operation of the substation for conversion of electricity;
- reports measuring the electric field and magnetic, containing the following data: the test, test name, date of test, technical prescriptions, test results in table;
- classification analysis / nonframings the values measured in the admissible limits.

It only shows the measurements made in the substation Iernut 400/220/110 kV (Figure 2), the Romanian Power Grid Company Transelectrica S.A. – Transmission Branch Sibiu.

The Iernut substation 400/220/110kV is an important bus within the National Power System (NPS) and the area north and central Transylvania in view of its multiple functions:

- the 400kV substation ensures the transit power from surplus areas of NPS to areas from Transylvania;
- the 220 kV substation NPS ensures evacuation of the power produced in thermo power-plant Iernut groups 125MVA-G1, G2-125MVA, G5 and G6-250MVA-250MVA;
- the 110 kV substation NPS ensures evacuation of the power produced thermo power-plant Iernut groups G3 and G4-125MVA-125MVA and power consumers in their own area.

The rehabilitation works (for the 3 existing substations) were completed for 400 kV and 220 kV, for the case of the 110 kV substation, they are

ongoing. For the Iernut substation measurements were effectuated in 20.10.2008.

The reference standards for measuring the magnetic field and maximum permissible magnetic induction B for personnel operating in the electrical installations frequency of 50 Hz are:

- IEC 61786/1998 - measurement of low frequency magnetic and electric fields with regard to exposure of Human beings - Special requirements for instruments and guidance for measurements;
- ANSI / IEEE Standard 644-1987 IEEE Standard Procedures for measurement of power frequency Electric and Magnetic Fields from Power Lines.
- CENELEC - Project of European standards ENV 50166-1, human Exposition aux champs électromagnétiques Basses fréquences (0 - 10 kHz) - 1995.
- General rules of safety set by the Ministry of Labor and Social Protection and the Ministry of Health - 1996.

CEI 61,786, ENV 50166-1 and the general rules for the protection of labor in Romania provide that the maximum allowable induction of the magnetic field $B = 0.5$ MT on exchange of work (for 8 hours daily). In the conditions under which staff are exposed to $B = 5$ MT duration of exposure will be less than 2 hours on the exchange work.

The results of the magnetic field measurements, for the case of the 400 kV Iernut substation, are given in Table 4. All values measured induction B are much lower than the maximum allowable $B = 0.5$ MT and therefore are not necessary measures to protect personnel action against the magnetic field.

The reference standards regarding the measuring of the electric field and maximum permissible electric field intensity staff operating in the electrical installations frequency of 50 Hz are:

- CEI 61786/1998 – measurement of low frequency magnetic and electric fields with regard to exposure of human beings – Special requirements for instruments and guidance for measurements.
- IEC 833/1987 – Measurement of electric field at ind.frequency. CENELEC - Project ENV European standard 50166-1, Human exposure to low frequency electromagnetic fields (0 - 10 kHz) - 1995
- General rules of safety set by the Ministry of Labor and Social Protection and the Ministry of Health - 1996.

CEI 61,786, ENV 50166-1 and the general rules for the protection of labor in Romania provide that the maximum permissible intensity of the electric field $E = 10$ kV / m for a time of 8 hours a day. In the conditions under which staff are exposed to $E > 10$ kV / m is recommended reducing the waiting time in the electric field using the formula $t = 80 / E$, where t is time in hours.

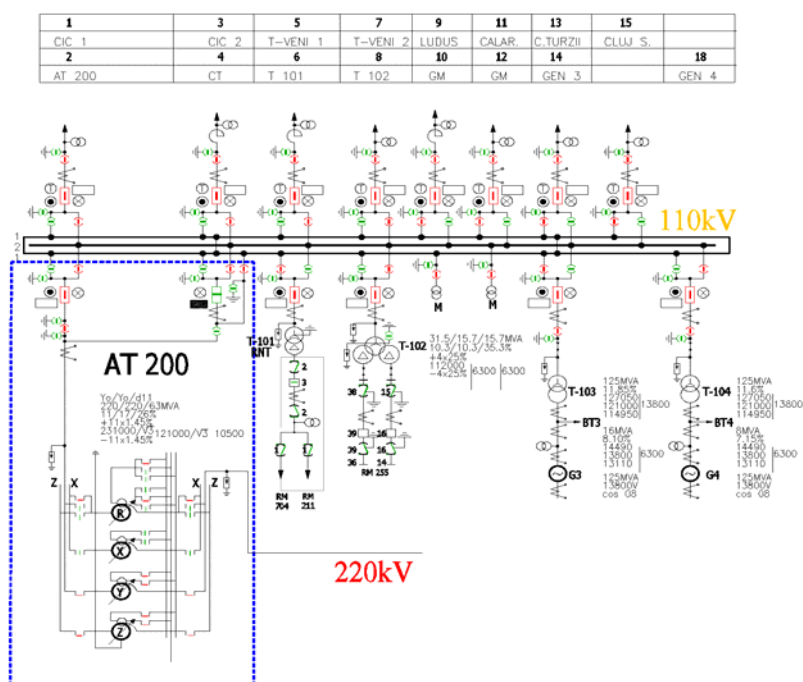


Figure 2. Iernut's substation oneline scheme

Results of electric field measurements on the 400 kV Iernut substation are given in Table 5. They conducted measurements in the 92 points and 66 points were found values of the intensity of the

electric field from 10 kV / m. In these areas with $E > 10$ kV / m necessary measures to protect staff in accordance with international and domestic rules.

Table 4. Magnetic field B (mT) measurement results. Case study: 400kV Iernut substation

No.	Measuring point	Magnetic field B [mT]		
		R	S	T
1.	Blocking inductance BI cell 5	0.018	0.020	—
2.	MOP-10 Mechanism cell 5	0.015	0.017	0.013
3.	DRV cell 5	0.013	—	0.011
4.	Voltage transformer cell 5	0.016	0.019	—
5.	Circuit-breaker IO cell 3	0.025	0.030	0.030
6.	Blocking inductance BI cell 3	0.028	—	0.022
7.	Circuit-breaker IO cell 2	0.015	0.018	0.013
8.	Circuit-breaker IO cell 1	0.019	0.014	0.014
9.	Relays cell 2	0.02		
10.	Relays cell 1	0.02		
11.	Voltage transformer cell 1	0.016	0.018	0.014
12.	Current transformer cell 1	0.012	0.014	0.011
13.	DRV cell 1	0.016	0.019	—
14.	At the autotransformer vat	0.3	0.3	0.45
15.	Command room	0.002		

Table 5. Electric field E (kV/m) measurement results. Case study: 400kV Iernut substation

No.	Measuring point	Electric field E [kV/m]		
		R	S	T
Cell 5 Gadalin				
1.	IO-MOP Mechanism	18 V/m	16 kV/m	16 kV/m
2.	SL Line separator	10 V/m	7 kV/m	9 kV/m
3.	IO Bracker	12 kV/m	10 kV/m	12 kV/m
4.	BB Blocking inductance	9 kV/m	11 kV/m	–
5.	VT Voltage transformer	13 kV/m	9 kV/m	11 kV/m

6.	DRV discharger	13 kV/m	9 kV/m	11 kV/m
7.	BS 1 Bars separators 1	13 kV/m	10 kV/m	13 kV/m
8.	BS 2 Bars separators 2	11 kV/m	8 kV/m	9 kV/m
9.	B1 Under bars 1	16 kV/m	16 kV/m	16 kV/m
10.	B2 Under bars 2	11 kV/m	9 kV/m	11 kV/m
11.	VT-B1 Voltage transformer	12 kV/m	10 kV/m	12 kV/m
12.	VT-B2 Voltage transformer	9 kV/m	7 kV/m	9 kV/m
T: 35p-21p>10kV/m				
CELL 1				
13.	VT Voltage transformer	13 kV/m	12 kV/m	16 kV/m
14.	CT Current transformer	16 kV/m	13 kV/m	15 kV/m
15.	Under bars B	12 kV/m	10 kV/m	12 kV/m
16.	DRv Discharge	13 kV/m	13 kV/m	16 kV/m
17.	BS Bars separator	12 kV/m	10 kV/m	13 kV/m
18.	IO-MOP Bracker Mechanism	16 kV/m	14 kV/m	16 kV/m
T: 18p-16p>10kV/m				

5. Conclusion

The monitoring system presented within the paper, allows:

- measurement of electric field intensity for specific jobs staff operating and maintaining Overhead Power Lines and substations of 220 kV and 400 kV;
- measurement of magnetic induction for specific jobs staff operating and maintaining overhead power lines and substations of 220 kV and 400 kV;
- determine the numerical analysis of the electric field distribution and the magnetic field in case of 220 kV and 400 kV Overhead Power Lines, built values measured in a limited number of points;
- evaluation and induced biological effects of electric and magnetic field and the risk factors of professional sickness staff operating and maintenance of electrical installations of high voltage (220 kV, respectively 400 kV);
- establish concrete measures to protect the personnel operating within the 220 kV and 400 kV equipment against electric and magnetic fields. As conceived it can be integrated in the monitoring of the power quality described in [12] and [7].

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