POWER SUPPLY OF INSTALLATIONS FOR DECONTAMINATION OF SOIL POLLUTED WITH TRANSFORMER OIL - AN EXPERIMENTAL STUDY

ALIMENTAREA INSTALAŢIILOR DE DECONTAMINARE A SOLURILOR POLUATE CU ULEI DE TRANSFORMATOR. STUDIU EXPERIMENTAL

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Abstract: *Protecting the environment and reducing the negative impact of industrial activities on the environment has led, among other things, to intensify efforts to develop new methods for the depollution of contaminated areas with different pollution products. The human impact on the environment, in order to produce and use energy has led to an important change in the normal course of the planet, implicitly of our daily lives. For the decontamination of soils polluted with transformer oil in power plants and transformers stations, a series of specific technical elements are presented, which highlight the relevant technical and economic values.*

Keywords: Protecting the environment, depollution.

Rezumat: *Protejarea mediului și reducerea impactului negativ al activităților industriale asupra mediului au condus, printre altele, la intensificarea eforturilor de a dezvolta noi metode de decontaminare a zonelor contaminate. Impactul uman asupra mediului, pentru a produce și utiliza energie electrica, a condus la o schimbare importanta în cursul normal al evolutiei planetei, implicit al vieții noastre de zi cu zi. Pentru decontaminarea solurilor poluate cu ulei de transformare în stațiile electrice și in posturi de transformare se prezinta o serie de elemente tehnice specifice cu evidențierea unor valori tehnico-economice relevante.*

Cuvinte cheie: Protejarea mediului, decontaminare.

1. Introduction

Regarding Romania's attitude towards sustainable energy development, the first step was taken in 2008 when Romania's National Strategy for Sustainable Development was developed, which aims to protect

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the integrity of the natural environment and maintain a sustainable balance. EU action programs include reducing greenhouse gas emissions, conserving biodiversity, protecting and maintaining superior water and soil quality by reducing waste.

In terms of environmental protection, its objectives are:

- Ensuring environment protection according to economic needs and the geographical area in which the source of pollution is located.
- Creating an environment conducive to a healthy life and at the same time ensuring a high level of quality of social life of every citizen by encouraging the use of renewable and low-polluting resources.
- Cooperation with third countries to find and solve regional, local or national problems to combat global warming.

This paper focuses on 400 kV / 110 kV High Voltage (including 220 kV) and Medium Voltage (between 1… 110 kV) in electric line and power transmission and distribution installations, where oil losses can occur from transformers in various electrical equipment with operation especially with oil and special Vaseline that can pollute the surrounding soil.

Microwave installations can be used to decontaminate soils affected by oil spills. Microwaves are electromagnetic waves with a frequency between 300 MHz and 300 GHz and are used as heat sources of dielectric materials.

The wavelength formula is [4,5,23]:

$$\lambda_0 = \frac{c_0}{f}, \tag{1}$$

where f is the frequency and c_0 is the speed of light in vacuum [4,5]:

$$c_0 = \frac{1}{\sqrt{\varepsilon_0 \cdot \mu_0}}. \tag{2}$$

Microwaves can produce in liquid or solid phase the dielectric heating effect that is produced by the electrical component of the field that exerts a force on the charged particles.

The microwave technique used in this paper is based on the use of highly absorbent ceramic microwave materials, which develops a thermal oxidation (post-combustion) effect of the pollutant emissions (CO, SO2, NOx, volatile organic components VOC) resulting from the incineration of losses, from dangerous transformer oil.

Theoretical and experimental aspects of the microwave field behavior of these materials are presented in various variants, the maximum temperature levels obtained to ensure the thermal regime of oxidation of the polluting emissions and the temperature rise slope for different levels of microwave power. Nowadays, the problem of used materials is becoming more and more serious, due to their increasing quantity and the negative impact on the environment.

2. Decontamination of soils polluted with petroleum products

Microwave treatment of materials and especially of soils impregnated with petroleum waste (soils affected by a certain degree of humidity) is based on the property of the material (soil) to selectively absorb microwave energy through the phenomenon of dielectric polarization due to the influence of the microwave field. The phenomenon is even more pronounced as the structure of the pollutant (petroleum products, mineral oils, chemicals, etc.) and the water has a polar configuration. Microwave in situ decontamination of contaminated soil can be done in two ways:

- with soil sampling, its treatment taking place in a fixed microwave decontamination installation;
- without taking the soil, using a mobile microwave equipment, which can move above the polluted area of the soil, dissipating the energy of the microwave in it.

The study of the behavior of materials in the microwave field is performed mainly by:

- studying the two essential parameters in the design and operation of microwave installations: the power reflected in the microwave and the standing wave factor;
- studying the dielectric properties of the materials treated in the microwave field (variation of the dielectric constants of the material with temperature, humidity, frequency);
- studying the evolution of the temperature of the material treated in the microwave field and evaluating the power level in the microwave needed to carry out the thermal process.

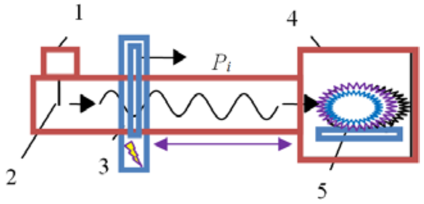
Preliminary laboratory experiments were performed on thin layers of unpolluted or polluted soil. The experiments were carried out on thin layers of soil contaminated with petroleum products deposited on a metal support and aimed at the experimental determination of the main parameters that ensure the proper functioning of the microwave generator system (the stationary wave factor and the reflected power).

3. The monitoring scheme used

The simplest microwave circuit is shown in Figure 1-a. When microwave source is put into operation, it emits an electromagnetic wave that transports the incident power P_i (direct or transmitted power) to the charge.

The use of microwave energy, generally for the purpose of thermal processing of materials, is carried out in an enclosure with metal walls, realized in an electrically sealed construction, in which microwave energy is injected. Enclosures of this kind are found in the specialty literature under the name of microwave applicators [7,8,9,23].

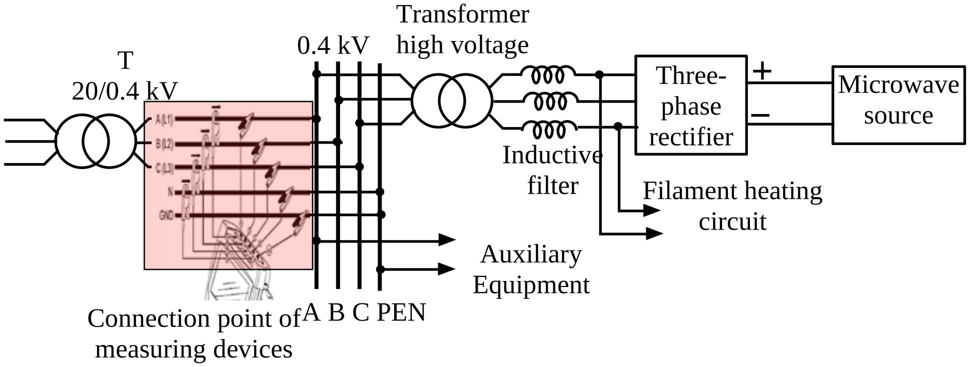
Figure 1-b shows the schematic diagram of the analysed installation, supplied from the 20 kV network of the power distributor [3,9,23]. The diagram includes a transformer which, together with a three-phase rectifier, provides the DC voltage necessary for the operation of the microwave source and a single-phase transformer which allows the supply of auxiliary equipment of the installation.



where:

1. Microwave source; 2. Bi-directional coupler; 3. Adaptation system; 4. Applicator; 5. Heating material.

a. The simplest microwave circuit



b. Schematic diagram of the analysed installation

Figure 1 - Schematic diagram of the analysed microwave installation

In connection point of measuring devices, 7600 ION (Fluke 453) Class A ensures high accuracy measurement of the actual values of voltages and electric currents, electric power and energies. The readings are updated every cycle and every second. The equipment allows the analysis of the following quantities: effective values of the line and phase voltages;

effective and average values over a time interval of the electric currents, on each phase and on the neutral and protection earth conductor; active, reactive power, apparent on each phase and in total; the power factor on each phase and in total; electric current and voltage unbalance; reversing the direction of power flow for each phase; frequency of primary signals; voltage fluctuations (flicker); ensures the online analysis of the disturbances in the electrical network [10,11,12,13].

The following are the main parameters that characterize microwave applicators are:

- The resonant frequency of the applicator f_0 - is calculated using the following formula [4,5,8,14,23]:

$$f_0 = \frac{c_0}{2} \cdot \sqrt{\left(\frac{x}{a}\right)^2 + \left(\frac{y}{b}\right)^2 + \left(\frac{z}{c}\right)^2} \tag{3}$$

where:

c_0 is the speed at which light propagates in a vacuum ($c_0 = 3 \cdot 10^8$ m/s);

a, b, c – the internal dimensions of the applicator [m];

x, y, z – indications of the oscillation mode of the applicator [dimensionless].

The quality factor of the applicator Q is calculated with the formula [4, 6]:

$$Q = \frac{\omega \cdot W}{P_p}, \tag{4}$$

where W is the reactive energy stored in the cavity under permanent regime; P_p – the energy dissipated during a period in the processed material and in the walls of the applicator [1,2,13,15].

- Power density [W/m^3] is the power dissipated in the unit of volume of material exposed to the microwave field and is given by the formula [1,2,10,11]:

$$\begin{aligned} P_V &= (\sigma + \omega \cdot \varepsilon_0 \cdot \varepsilon'') \cdot E^2 = \\ &= \omega \cdot \varepsilon_0 \cdot \varepsilon''_g \cdot E^2 = \omega \cdot \varepsilon_0 \cdot \varepsilon_r \cdot \tan\delta \cdot E^2 \ . \end{aligned} \tag{5}$$

where [4]: $\sigma \cdot E^2$ - conduction losses;

ω - microwave pulsation [rad/s];

ε_0- the dielectric permittivity of the free space[F/m];

ε''- the relative loss factor;

E- intensity of electric field [V/m].

The objective of these experiments consists in the experimental determination of the main parameters that ensure the good functioning of the microwave generating system and the verification of the behavior of the radiation system in real operating conditions.

The purpose is also to determine the impact of the operation of the microwave system on the power supply network through disturbances that may occur due to the nonlinear circuit of the sources and the uneven load of the phases of the power supply network [13,14,15].

4. Soil protection and decontamination

Microwave material treatment is a new method, which improves the physic-chemical properties of materials, provides efficient alternatives for processing materials difficult to process with conventional methods, does not produce toxic emissions in the environment during material treatment, provides spectacular economic benefits by reducing substantial, from a few tens to a few hundred times the time required to process the materials, allows the obtaining of new materials and microstructures that cannot be obtained by other known physical methods. The advantages of using microwaves in the processing of materials have led to an extremely rapid transfer of methods from the laboratory scale to the industrial and commercial scale [14,15,16].

Hydrocarbons are the main compounds of petroleum, and they can be in the following classes of hydrocarbons:

- Hydrocarbons (saturated acyclic) (CnH2n+2);
- Hydrocarbons (saturated cyclic) (CnH2n);
- Hydrocarbons (unsaturated or aromatic cyclic) (CnH2n-6).

The most important properties of petroleum products in terms of interaction with the soil are:

- State of aggregation (mixture of liquid compounds);
- Hydrophobic character;
- High carbon content (85%);
- High carbon-nitrogen ratio.

5. Analysis of electrical elements

Installations equipped with frequency converters and other nonlinear elements can cause distortions of absorbed current curves, asymmetries and voltage fluctuations (flicker phenomenon). In order to highlight these phenomena, measurements were performed at the supply terminals, every 5 seconds.

Figure 2 shows the voltage variation at the 0.4 kV supply bars at which the installation was supplied. Voltage curves have a similar appearance, leading to an unbalance of line voltages within the permissible limits (about 0.75%). It can also be observed that during the study, the voltage at the 0.4 kV bars was within the permissible limits of variation (about 0.9%) [1,2,16,17].

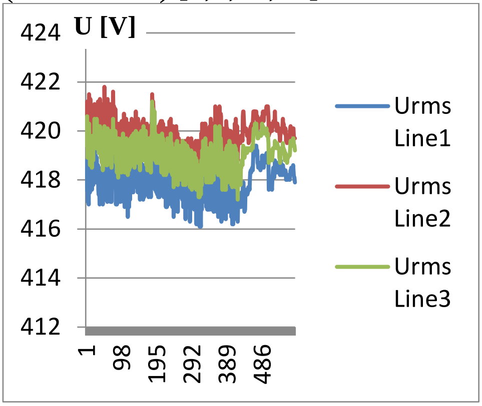


Figure 2 - Voltages variation on the 0.4 kV power bar during the study carried out

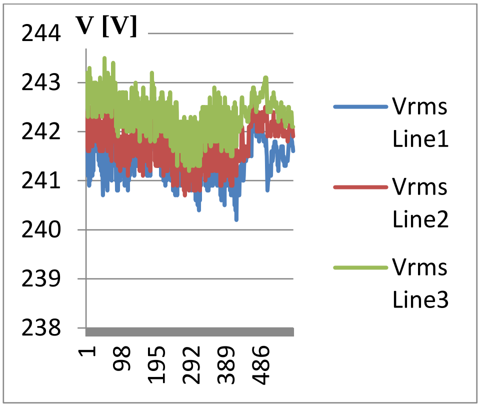


Figure 3 - Variation of the supply voltages per phase at the supply bars

The analysis of the data in Figure 3 reveals an unbalance factor V_{unb} of about 0,5%, which indicates the existence of single-phase users connected in the low-voltage network, unevenly on the three phases, leading to different voltage falls over the three phases.

Variation of the measured values of the negative unbalance factor $Vunb$ determined as the ratio between the negative sequence component U^{-} of the voltage curve and the positive sequence component U^{+} of the voltage curve

$$V_{unb} = \frac{U^{-}}{U^{+}} \ , \tag{6}$$

is indicated in figure 4 and figure 5.

Special power schemes have been proposed to achieve symmetrization of electric currents in the analyzed network [1,2,3,12].

Although the user includes several non-linear sources (frequency converters, controlled rectifiers, etc.) the user has taken effective measures to limit the distortions of electric current curves so that the voltage distortion factor k_{dU}, determined as the ratio between the residual voltage U_d and the fundamental harmonica $U_1$of the tension at the bars of 0.4 kV

$$k_{dU} = \frac{U_d}{U_1} \ , \tag{7}$$

within the limits allowed by the current regulations (Figure 5), with values not exceeding 1 % (compared to 8% allowed in the standards) [1,2,18,19]. Figure 6 shows the result of the monitoring of electric currents, from the point of view of their distortion.

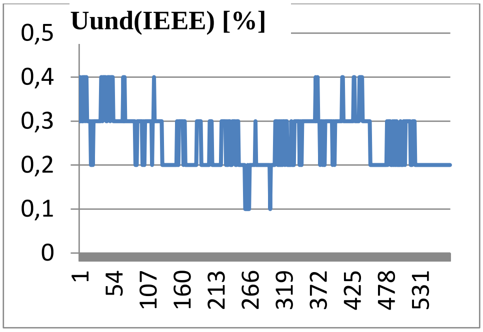


Figure 4 - Variation of voltage unbalance the low voltage bars of the user

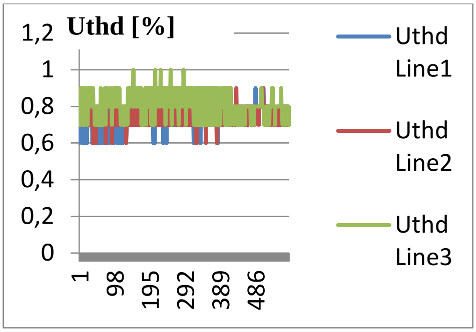


Figure 5 - Variation of voltage unbalance at voltage bars of the user on all monetarised periods

Harmonic analysis of voltage curves has highlighted the presence in particular of rank 5 and 7 harmonics that can cause damage in the operation of some users (Table 1). The harmonics with a multiple rank of three, although they appeared in the voltage curve, are of low values, so it is no longer necessary to limit these harmonics in the triangle winding of the transformer 20/0.4kV [1,2,18,19].

Table 1 - *The impact of the deformant regime on receivers*

Distortion factor of the voltage curve	**The consequences of long-term exposure**
kdu ≤ 5%	In the most cases there are no problems
5% < *kdu* ≤ 7%	Problems may arise in highly sensitive equipment
7% < *kdu* ≤ 10%	Problems may also occur in robust elements
kdu > 10%	Damage may occur

In order to limit the harmonic content in the user scheme, solutions have been proposed related to the proper connection of converters [1,2,3].

The data in Figure 6 indicate that the electrical current distortion factor, can reach relatively high values. The reduced internal impedance of the power supply shall cause the level of voltage harmonics at the power bars not to exceed the limits permitted by the standards in force [1,2,3,18,19].

Harmonics with a rank above 50 were not analyzed having insignificant values. A particular attention was paid to monitoring the values of electrical currents in the supply circuits to determine both their demands and the level of losses in the user's electrical circuits. The recorded data did not reveal any exceedances in the form of a flicker [1,2,19,20].

The ranked curves of the active and reactive power required by the user (Figure 7 and Figure 8) as well as the analysis of the variation of the power factor (Figure 9).

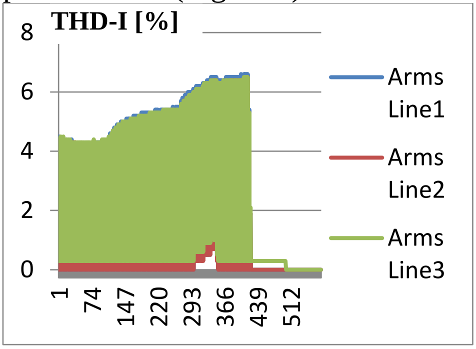


Figure 6 - Variation of the total harmonic distortion factor of the electric current curves on the analysed circuit

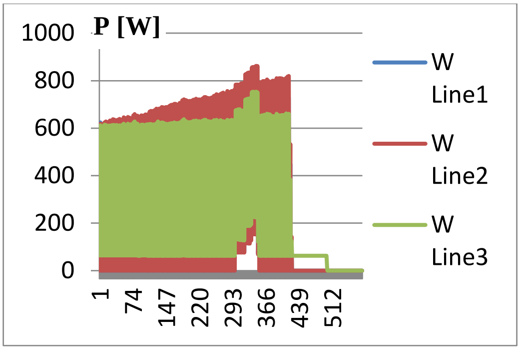


Figure 7 - The ranked curves of the active powers for the three phases of the analysed electrical circuit

Based on the data in Figure 9, it is noted that the capacitive power factor values are within the limits accepted by the regulations in force. In order to ensure the control of reactive power concrete solutions have been analyzed.

The PF power factor was determined by the base of the recorded energy values over a specified time interval [1,3,21,22,23]:

$$PF = \frac{W_{trifazat}^{P}}{W_{trifazat}^{S}}, \tag{8}$$

The PF value, although widely used in the practical applications, provides accurate information on the energy behavior of the consumer only in the case of a constant consumption over the period in which the power factor assessment is made.

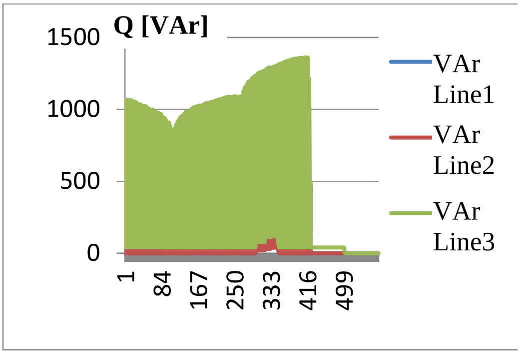


Figure 8- Variation of reactive powers during the time of monitoring

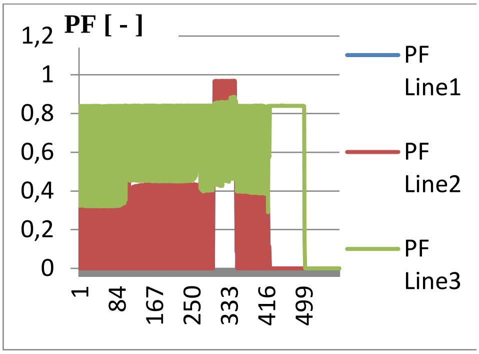


Figure 9 - The variation of the power factor in the monitored range

6. Conclusions

This "Pilot for real-test", in a laboratory test stage, has another type of microwave-susceptible ceramic material, which can develop a temperature of around 2200 – 2800 °C. We consider that these Pilot are used in incinerators, as well as in other industrial applications with polluting emissions.

The use of microwave energy in various types of industrial applications has led to increased process efficiency, lower costs and ultimately increased profits, by recovering many types of materials and saving a large amount of energy.

The parameters that characterize the microwave irradiation of materials and especially of soils and pollutants (petroleum products) were analyzed, in order to apply the decontamination treatment by microwave heating.

The measurements were performed with high-performance Class A monitoring equipment on the low voltage secondary circuit of the power supply transformer of the analyzed section. In the analysis of voltage and current distortions, it is necessary to take into account the variations of active power, reactive power and power factor.

The monitoring of voltage curves at the power bars represents an important interest in determining of the power quality, supplied by the local electricity distributor. Monitoring of current curves is important for assessing user-driven disturbances transmitted to the distributor's circuits.

The presence of a modern monitoring system in the analyzed user allows the obtaining of the most important information on its energy behavior, but also it limits the electromagnetic disturbances generated by the technological process and the adoption of intelligent measures to increase the user's performance.

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