HIGH ALTERNATIVE VOLTAGE, ADJUSTABLE SOURCE WITH THREE-PHASE SUPPLY, MADE FOR OZONE GENERATORS

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Se prezintă o sursă electrică statică de înaltă tensiune şi medie frecvenţă (15…20kV(varf);800…1200Hz), alimentată trifazat, care funcţionează în tandem cu ozonizorul în cadrul unei instalaţii de putere medie sau mare, pentru producerea industrială a ozonului prin metoda descărcării corona.

În lucrare sunt tratate: principiul funcţionării sursei în rezonanţă de tensiune cu ozonizorul; relaţiile de calcul; algoritmul programului de calcul dezvoltat pentru evaluarea regimului de funcţionare (formele de undă ale curenţilor şi tensiunilor) şi determinarea valorilor componentelor electrice ale sursei.

The paper presents a static electrical high voltage and medium frequency source (15…20kV(peak voltage);800…1200Hz) with three-phase supply, that functions together with the ozonizer in a medium or high power system that produces ozone industrially through the corona discharge method.

The paper explores: the functioning principle of the source in voltage resonance with the ozonizer; calculus relations; the algorithm of the calculus program developed to evaluated of the working regime (the wave form of the currents and voltages) and calculus values of the electrical components of the source

Keywords: ozone, high voltage source, calculus program algorithm

1. Introduction

Ozone O_3 can be obtained chemically, through ultraviolet radiation or physically, through corona type discharges. The physical method is used industrially by creating a corona discharge in the prepared air or in oxygen, for medicine or pharmaceutical uses. The ozone has a high oxidation capacity, the oxidation speed of *600-3000* times faster than that of chlorine doesn't leave any residue and doesn't have any secondary polluting effects, because after *60* min. it goes back to its O_2 state. The ozone can be obtained by dissociating an oxygen molecule O_2 and combining one of the resulting atoms with an oxygen molecule. The reaction through which ozone is created is reversible of this form:

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$3O_2$+288,8kJ ↔$2O_3$, in which *144,4kJ* are consumed for a mol of *O_3.* (1)

The most important uses for ozone are: • *In the food industry to destroy*: insecticides and nutrients traces from fruit and vegetables bacilli, dysentery, viruses, etc.; •*To purify drinking and industrial water* : it destroys chlorine, viruses, bacteria, microorganisms, cyanide, phenols, sulfurs, chloroform substances, detergents, it oxidants iron, manganese and other heavy metals etc.; • *In medicine and hygiene*: to treat some diseases, disinfection, removing unpleasant scent of tobacco, mold etc.;
• *In industries:* cellulose, kaolin, textiles, chemicals, pharmaceuticals etc.

2. The conditions imposed to the high voltage source. The power wiring diagram of the three-phase supply source

The static high voltage sources that supply the low power (under *5kW*) ozone generators can be supplied from the single-phase *230V/50Hz*. The ones for medium (*5-100kW*) or high *(>100kW*) power generators will be supplied from the three-phase network *3x400V/50Hz* or another higher value (fig.1).

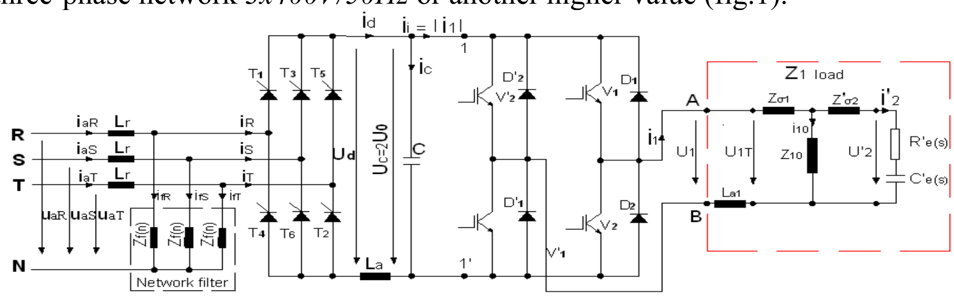


Fig.1.The power wiring diagram of the high voltage, three-phase supply source for ozone generators

The high or medium power ozone generators, with cylindrical or plane geometry, from an electrical point of view are equivalent with a capacitive-resistive load $C_{e(s)}R_{e(s)}$ with a more pronounced capacitive character. Together with the inductive circuit of the high voltage transformer (from which the current without a load can be neglected: $i_{10} \approx 0$), the inverter's load Z_1 (fig.1) becomes a resistive-inductive- capacitive type, in which:

$$R_1 = R_{e(s)}\big/k_T^2 + R_{1sc} + R_{a1}\,;\, L_1 = L_{a1} + L_{1sc}\ ;\ C_1 = C_{e(s)}k_T^2 \qquad (2)$$

where:

$R_{e(s)}$ -is the equivalent series resistance of the ozonizer that is determined by measurements on the discharge element (tube, cell) depending on the active consumed power;

$k_T = w_2/w_1$ - is the transformer ratio of the high voltage transformer;

R_{1sc}, L_{1sc} - The resistance, the short-circuit inductivity of the high voltage transformer, transposition in the primary;

R_{a1}, L_{a1} - The resistance, the inductivity of the additional inductance L_{a1};

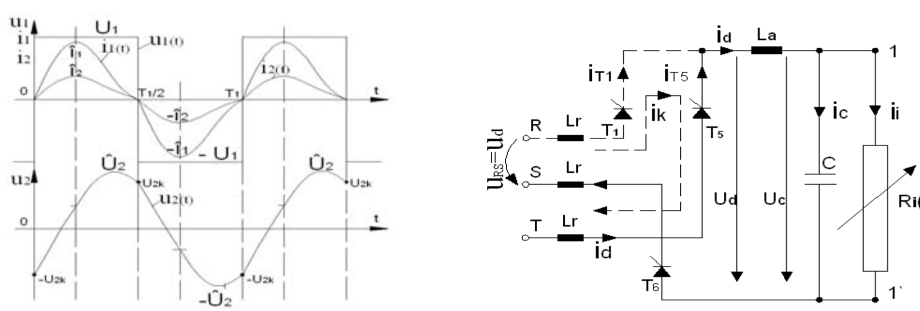
$C_{e(s)} \cong C_d$ - The dielectric's (glass, ceramics) capacity of the ozonizer; it is calculated for one element then multiplied by the number of elements.

The main conditions imposed to the high voltage source are:

a) The functioning of the inverter in voltage resonance regime with the load (switch to zero current, $i_1(t) = 0$ fig.2.a) that ensures:

− minimum switch losses on the inverter's transistors;
− maximum active power transfer from the d.c. intermediary circuit to the load;
− choosing the optimum values for the elements of the source: filters, transistors, thyristors, high voltage transformers etc;

b) The ripple of the voltage on the *C* capacitor (fig.1) must be reduced under *10%* ($r_{uc} < 10\%$), because the ozone generators with corona discharge are sensitive to the peak value variations of the supply voltage $\hat{U}_2$



a) b)

Fig.2. a) The variation diagrams of the currents and voltages from the power circuit inverter-load. b) Current pathways of the power wiring diagram from fig. 1 being in conduction; the inverter is equivalent to a time variable resistance-$R_i(t)$

3. The analysis of the high voltage source's functioning
3.1 The expression of the current through the inverter. The equivalence

between the inverter-load circuit and the time variable resistance (conductance). When the source functions (fig.1) with the inverter in voltage resonance with the load, the current $i_1(t)$ of the primary circuit of the transformer can be written as:

$$i_1(t) = i_i(t) = U_1 \frac{2\gamma}{(\gamma-1)\omega_1 L_1} e^{-\alpha_1 t} \sin\omega_1 t, \quad \text{in which:} \tag{3}$$

$t = [0, T_1/2], T_1 = 1/f_1, f_1 =$ load voltage frequency (of the inverter's switch);
$U_1 \cong \overline{U}_c$ – Medium voltage (filtered) in stabilized regime on the C capacitor;

$$\gamma = e^{\pi\alpha_1/\omega_1}\ ; \quad \omega_1 = \sqrt{\omega_0^2 - \alpha_1^2} = 2\pi f_1 - \text{ Load voltage angular frequency;} \tag{4}$$

$$\omega_0 = 1/\sqrt{L_1 C_1} - \text{The inverter's load's own angular frequency } R_1, L_1, C_1; \tag{5}$$

$\alpha_1 = R_1/2L_1$ – Current damping coefficient.

This expression of the current $i_1(t)$ is matches the equivalent series circuit R_1, L_1, C_1;
"excited" by the rectangular alternative voltage $u_1(t)$ (fig. 2.a).
The circuit has to operate in an oscillation damping regime, so we impose the mandatory condition that: $\omega_0 > \alpha_1$
The conductance $G_i(t)$ and the resistance $R_i(t)$ are defined as time variable and equivalent to the inverter-load circuit at terminals 1-1' (fig.1):

$$G_i(t) = 1/R_i(t) = \frac{2\gamma}{(\gamma-1)\omega_1 L_1} e^{-\alpha_1 t} \sin\omega_1 t \tag{6}$$

In the expression of the conductance $G_i(t)$, writing G_i as the fixed part we have:

$$i_1(t) = i_i(t) = U_1 G_i e^{-\alpha_1 t} \sin\omega_1 t, \text{ in which: } G_i = \frac{2\gamma}{(\gamma-1)\omega_1 L_1} \tag{7}$$

In this way the equivalent circuit diagram of the source coupled with the load is simplified so that the inverter-ozonizer circuit can be equivalent to a time variable resistance $R_i(t)$, the resulting equivalent circuit diagram being presented in fig.2.b. ***3.2 The expression of the instantaneous rectified voltage: u_d (t).*** The instantaneous value of the rectified voltage is obtained from the difference between two phase instantaneous voltages, in this case $u_R(t') - u_S(t')$, in which the thyristor T_5 switches with T_1 at the moment $t = 0$ (fig.2b) so that :

$$u_d(t) = \sqrt{6} U_r \cos(\omega_r t + \theta - \pi/6), \tag{8}$$

in which: U_r -is the effective value of the phase network's voltage;

$\omega_r = 2\pi \cdot f_r = 2\pi/T_r$;
$f_r = 50Hz, T_r = 20ms$ -Frequency, respectively the period of the network's voltage; $t = [0, T_r / 6]; \theta = [0, \pi]$-the theoretical command (turn on) angle of the thyristors.

3.3 The expression of the medium rectified voltage in continuous current Regime: id (t)>0

Is obtained by integrating the rectified voltage $u_d(t)$ on its period, $T_r / 6$:

$$\overline{U}_d = \frac{6}{T_r} \int_0^{Tr/6} \sqrt{6} U_r \cos(\omega_r t + \theta - \pi/6) dt = U_{d0} \cos\theta \ , \qquad (9)$$

in which: $U_{d0} = 1{,}35 U_l ; U_l = \sqrt{3} U_r$; -the effective value of the line voltage from the rectifier's terminals; $\theta = 10...150^\circ el$ - in practice, the variation interval of the angle θ is getting smaller.

4. Elaborating the calculus program for the electrical quantities from the source-ozonizer system

In the power wiring diagram from fig.1 all the constitutive elements have to be calculated: the high voltage transformer, inverter, the filter of the intermediary d.c. circuit, commanded rectifier, network filter. This means that it's necessary
to determine the currents and the voltages that solicitate these elements, as well as the values of the intrinsic quantities so that the components can be selected. The power wiring diagram of the source together with the ozonizer forms a system in which the variable quantities (currents, voltages), in a stabilized regime, have a repetitive evolution from a cycle to another or nonrepetitive, in a transient regime. The mandatory state quantities that determine the evolution in time of the system are:

- -the current through the inverter: $i_i(t) = |i_1(t)|$;
- -the instantaneous rectified voltage: $u_d(t)$.

The source-ozonizer system is described by a number of equations and differential equations, the analytical solving of which is very difficult. To surpass this inconvenience we will be using the **method of the small (infinitesimal) variations.** For this purpose the time of a current alternation $T_1 / 2$ of $i_i(t)$ load is divided in n equal intervals τ_0, in which τ_0 is the constant discretization interval of variable t called *discretization step,* with $\tau_0 <<< T_1 / 2 << T_r$, respectively $\tau_0 = T_1 / 2n$ and $n =$ whole number. The network cycle (*j*) with the time of $T_r / 6$ will have qn intervals τ_0, (q =or ≠ whole number), q - number of alternating currents i_i of $T_1 / 2$ time, contained in a cycle (*j*) with $j = 1...m$, (j - cycle counter), m -number of considered cycles. The other variable in time quantities' expressions will be adapted according to this "discretization" so that the calculation of these system values is to be made step by step from an interval (k) to the next ($k+1$) using recurrence relations.

4.1 The load $i_i(t)$ current. Because the condition of the infinitesimal interval $\tau_0 <<< T_1 / 2$ has been imposed, on a interval *k,* the current $i_{i(k)}(t)$ can be linearized:

$$i_{i(k)}(t) = I_{i(k)0} + m_k t\,;\; m_k = [i_i(k\tau_0) - i_i((k-1)\tau_0)] / \tau_0\,;\; I_{i(k)0} = i_i((k-1)\tau_0) \quad (10)$$

$t = 0...\tau_0$, for the interval k .

The $i_i(k\tau_0)$ current that exists at the end of every *k* interval is calculated with:

$$i_i(k\tau_0) = GiU_1 e^{-\alpha_1 k\tau_o} \sin(\omega_1 k\tau_0)\,. \quad (11)$$

4.2. The rectified voltage $u_d(t)$.

$u_d(t)$ from the relation (8), noted in the discretized representation of $U_d(w)$, can be considered having constant value on the w interval and equal with medium value on that interval:

$$U_d(w) = \sqrt{6}U_r \cos[\omega_r \tau_0 (w - 0{,}5) + \theta - \pi/6]\;, \quad (12)$$

where $w = 1,2,3...T_r / 6\tau_0$ - counter that integrates the number of steps τ_0 in a cycle (*j*); at the $w = T_r / 6\tau_0$ moment w resets and begins the monitoring of the next cycle $(j+1)$ from $w = 1,2,3...$; w modifies at the same time with the *(k)* counter.

4.3. The differential equations of the source-ozonizer system. For the (*k*) interval of a semi alternating current from the (*j*) cycle, Kirchhoff theorems apply:

$$U_d(w) = L\, di_{d(k)}(t) \big/ dt + u_{c(k)}(t) \quad (13)$$

$$i_{d(k)}(t) = i_{d(k)}(t) + i_{i(k)}(t) = C\, du_{c(k)}(t) \big/ dt + I_{i(k)0} + m_k t \;;\quad \text{with: } L = L_a + 2L_r\,.$$

From these two equations, a quadratic equation results:

$$d^2 u_{c(k)}(t) / dt^2 + \omega_d^2 u_{c(k)}(t) = \omega_d^2 (U_d(w) - m_k L)\;, \quad (14)$$

with the general solution:

$$u_{c(k)}(t) = A\cos\omega_d t + B\sin\omega_d t + U_d(w) - m_k L\;, \quad (15)$$

in which: $\omega_d = 1 \big/ \sqrt{LC}$; A, B -integration constants; $t = [0, \tau_0]$.

The current through the capacitor $C, i_{c(k)}(t)$:

$$i_{c(k)}(t) = C\, du_{c(k)}(t) \big/ dt = -CA\,\omega_d \sin\omega_d t + CB\,\omega_d \cos\omega_d t\,. \quad (16)$$

The current through the coil $L, i_{d(k)}(t)$:

$$i_{d(k)}(t) = i_{c(k)}(t) + i_{i(k)}(t) = C\omega_d(-A\sin\omega_d t + B) + I_{i(k)0} + m_k t \ . \quad (17)$$

4.4. Establishing the recurrence relations used in the calculus program.

In the relations (15), (16), (17) the harmonic functions appear: $\sin\omega_d t$ and $\cos\omega_d t$, with $\omega_d t = 2\pi \cdot t / T_d$ in which $t = [0, \tau_0]$.

Functional condition 1. *The LC filter (fig.2b)* $L = L_a + 2L_r$*, must have a frequency own* $f_d << f_r$ *(*f_r *– network frequency), so that the ripple of the filtered voltage* U_c *to be under10%. Because the condition of the infinitesimal intervals was introduced from the beginning,* $\tau_0 \to 0$ *implicitly this inequality will be fulfilled:*

$$\tau_0 <<< T_d = 2\pi\sqrt{LC} \ , \quad (18)$$

next by developing in Taylor series the harmonic functions, we have:

$$\sin\omega_d t \cong \omega_d t \ \ \textit{And} \cos\omega_d t \cong 1\textit{; because } \omega_d t = 2\pi . t / T_d \to 0 . \quad (19)$$

According to this condition, the relations (15) and (16) become:

$$u_{c(k)}(t) = A + B\omega_d t + U_d(w) - m_k L \ ; \ i_{d(k)}(t) = C\omega_d(-A\omega_d t + B) + I_{i(k)0} + m_k t \ . \quad (20)$$

At the beginning of the k interval (the initial moment $t = 0$) we have:

$$U_{c(k)0} = A + U_d(w) - m_k L \quad (21)$$

From the relations (21) we can determine the A and B constants and after we substitute them in (20) we get:

$$u_{c(k)}(t) = U_{c(k)0} + [(I_{d(k)0} - I_{i(k)0})/C]t \ ; \ i_{d(k)}(t) = I_{d(k)0} + [(U_d(w) - U_{c(k)0})/L]t \quad (22)$$

The voltage on the C capacitor, as well as the current through the equivalent coil L, has continuity at the passing from (*k*) interval to (*k+1*), so we can write:

$$u_{c(k)}(\tau_0) = U_{c(k+1)0} \quad \text{and} \quad i_{d(k)}(\tau_0) = I_{d(k)0} \quad (23)$$

or explicitly, we obtain the ***recurrence relations*** between the (*k*) and (*k+1*) intervals;

$$U_{c(k+1)0} = U_{c(k)0} + \tau_0[(I_{d(k)0} - I_{i(k)0})/C] \ ;$$

$$I_{d(k+1)0} = I_{d(k)0} + \tau_0[(U_d(w) - U_{c(k)0})/L] \quad (24)$$

On a (*k*) interval, the voltage at the C capacitor's terminals increases/decreases linearly so that its medium value is:

$$\overline{U}_{c(k)} = 0{,}5[U_{c(k)0} + U_{c(k+1)0}];$$

or if the $U_{c(k+1)0}$ value is substituted in relation (24) we get:

$$\overline{U}_{c(k)} = U_{c(k)0} + [I_{d(k)0} - I_{i(k)0}]\tau_0 / 2C \ . \quad (25)$$

And the current through L also experiences a linear increase/decrease on the (k) interval, so we can write it:

$$\bar{I}_{d(k)} = 0{,}5[I_{d(k)0} + I_{d(k+1)0}].$$

If $I_{d(k+1)0}$ from (24) is substituted, results:

$$\bar{I}_{d(k)} = I_{d(k)0} + [U_d(w) - U_{d(k)0}]\tau_0 / 2L. \tag{26}$$

The medium current through the $R_i(t)$ load in the interval (k) can be linearized like all the other quantities:

$$i_{i(k)}(t) = I_{i(k)0} + m_k t,$$

$$\bar{I}_{i(k)} = \frac{1}{\tau_0}\int_0^{\tau_0} i_{i(k)}(t)dt = 0{,}5[I_{i(k+1)0} + I_{i(k)0}];$$

or if we write the current explicitly:

$$\bar{I}_{i(k)} = 0{,}5G_1\bar{U}_{c(k)}[e^{-\alpha_1\tau_0 k}\sin(\omega_1\tau_0 k) + e^{-\alpha_1\tau_0(k-1)}\sin(\omega_1\tau_0(k-1))] \tag{27}$$

Functional condition 2. *Conservation of the energy in capacitor C: in stabilized regime in any (j) cycle, the value of the voltage on the C capacitor at the beginning of the cycle has to be equal to the value of the voltage at the end of the cycle, consequently the medium value of the current that runs through the capacitor for one cycle to be null:*

$$\bar{I}_c = 6/T_r \int_0^{T_r/6} i_c dt = \sum_1^q \sum_{k=1}^n \bar{I}_{c(k)} = 0, \tag{28}$$

or in the calculus program, in the stabilized regime in any (j) cycle we must have equality of the medium currents: $\bar{I}_{d(j)} = \bar{I}_{i(j)}$.

The effective value of the current through the L_a coil:

$$I_{d(j)} = \sqrt{\frac{1}{w\tau_0}\int_0^{Tr/6} i_d^2 dt} = \sqrt{\frac{1}{w\tau_0}[\int_0^{\tau_0} i_{d(1)}^2 dt + \int_0^{\tau_0} i_{d(2)}^2 dt + \dots\int_0^{\tau_0} i_{d(\gamma)}^2 dt + \dots\int_0^{\tau_0} i_{d(w)}^2 dt]}$$

The partial integrals can be assimilated with the squares of the medium currents from the intervals τ_0:

$$\bar{I}^2{}_{d(\gamma)} = \frac{1}{\tau_0}\int_0^{\tau_0} i_{d(\gamma)}^2 dt,$$

and grouped semialternating currents q on any cycle (j) so that the final relation becomes:

$$I_{d(j)} = \sqrt{\frac{1}{w}\sum_1^q \sum_{k=1}^n \bar{I}_{d(k)}^2} \tag{29}$$

The effective value of the current that runs through the $R_i(t)$ load (fig.2b), $I_{i(j)}$ can be obtained through a similar method like the one used for $I_{d(j)}$ resulting:

$$I_{i(j)} = \sqrt{\frac{1}{w}\sum_{1}^{q}\sum_{k=1}^{n}\bar{I}_{i(k)}^{2}} \ . \qquad (30)$$

The effective value of the current through the *C* capacitor is obtained by applying Kirchhoff theorem for (k) interval in knot 1 (fig.2b):

$$I_{c(j)} = \sqrt{\frac{1}{w}\sum_{1}^{q}\sum_{k=1}^{n}(\bar{I}_{d(k)} - \bar{I}_{i(k)})^{2}} \ . \qquad (31)$$

The effective value of the i_R, i_S, i_T currents absorbed by the rectifier in a cycle (*j*) (fig. 1) is calculated with the relation:

$$I_R = I_S = I_T = 0{,}816 I_{d(j)} \qquad (32)$$

4.5. The flow chart of the calculus program.

To calculate the system quantities using the recurrence relations we previously established (24), we need a calculus program that will automatically ensure step by step of nq interval a $T_r/6$ cycle, or of more cycles (m), in which the extreme (min/max), medium, effective values are calculated and displayed. The flow chart of this kind of a program structured in the BASIC programming language is presented in fig.3. The calculus program
<<UI-RCD>> is conceived to allow as input values the following parameters:

- $G_i, \alpha_1, \omega_1 : Z_1$ load of the inverter;
- L, C : values of the continuous voltage filter (d.c.);
- U_r, θ : values of the three-phase supply network;
- $U_{c(w)0}, I_{d(w)0}$: initial values (program start) of the voltage and rectified current;
- τ_0 : value of the discretization step;
- m : number of calculus cycles (*j*) (the values are read at the end on the m cycle);
- ε : the correction variable of the current i_d (reduces the transient regime);

The program calculates step by step at every *k* interval the following quantities:

- $U_{d(w)}$ –the rectified network voltage -relation (12);
- $U_{c(w)0}$ –the voltage on the *C* capacitor of the continuous voltage filter-relation (24);
- $I_{i(k)0}$ –the current from the inverter (the sources load) - relation (11);
- $I_{d(w)0}$ –the rectified current through the continuous voltage filter- relation (24);

These quantities can be printed at scale with a plotter as graphs. If a plotter and the printing program are not available, the program <<UI-RCD >> has two routines

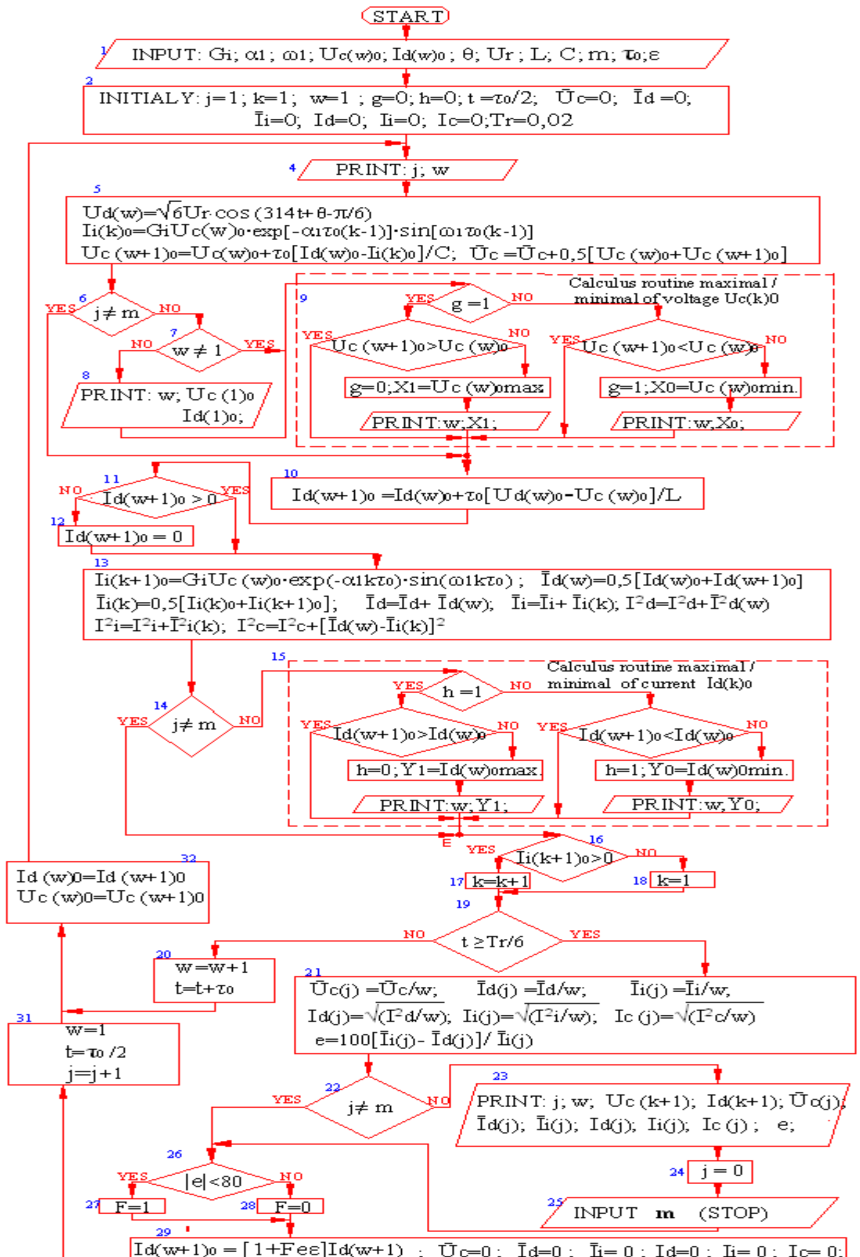


Fig.3. The flow chart of the calculus program <<UI-RCD>> of the parameters of the alternative and adjustable high voltage

implemented: calculates the extreme values (maximum/minimum) of the voltages on the filter capacitor $U_{c(w)0}$ and the rectified current $I_{d(w)0}$, so that we can build tables with the calculated values and eventually draw the graphs of the wave forms (fig. 4). The program also calculates the effective values of the currents: I_i − through the Z_1 load; I_d – through the L_a and L_r; I_c – through the C.

5. The achieved results

Fig.4 presents the wave forms of the rectified voltages $u_d(t)$, filtrated voltages $u_c(t)$, of the load currents (inverter) $i_i(t)$ and rectified $i_d(t)$ for a source designed to supply an ozone generator of *8kW* (in the process of being manufactured), with an alternative voltage of *17kV*(peak) at *1000Hz*, the values being calculated by the <<UI-RCD>> program, implemented on a programmable computer in BASIC language. The Z_1 load of the inverter (fig.1) has the following numerical values:

$$R_1 = 17{,}6\Omega ; L_1 = 16mH ; C_1 = 1{,}57\mu F ; G_i = 82{,}86mS ; \alpha_1 = 550s^{-1} ;$$

$\omega_1 = 6282rad/s$; $T_1 = 1ms$ and they match the transposition in the transformer's high voltage primary of the equivalent load of the *8kW* ozonizer, which consists of 15 glass tubes $\Phi 25/1500mm$ that have an internal silver layer−h.v. electrode.

The discretization step is: $\tau_0 = 10\mu s$, which in relation to the time of a semialternating current, $2\tau_0 / T_1 = 0{,}02 \to 0$, becomes infinitesimally (negligible), which ensures a very good calculating precision. The <<UI-RCD>> program for the calculus of the source-ozonizer system started from initial zero values: $U_{c(1)0} = 0; I_{d(1)0} = 0$ and the constant rectifier command angle ($\theta = 0{,}6423rad$), after almost *30* cycles $T_r/6$ *(j>30)* the transient calculus regime already passed, so that in fig.4 is presented a rated stabilized repetitive regime. We can observe that the controlled rectifier functions in a continuous conduction regime with a maximum current $I_{d\max} = 30{,}6A$ reached at $0{,}55(T_r/6)$, at almost half the cycle, which gives the current a sinusoidal pace. We also observe that the initial value of the rectified current $I_d(0)_0 = 6{,}26A$ differs a little from the value at the end of the cycle $I_d(T_r/6)_0 = 6{,}96A$; this difference comes from the fact that: $q = (T_r/6)/(T_1/2) = 6{,}66 \neq$ whole number, which can be explained, because the value of the current *i*$_i$*(t)* at the beginning of the cycle is different from the value at the end of the cycle (fig.4). If $q =$ whole number (a very particularly case), then we would have $I_d(t)_0 = I_d(T_r/6)_0$. The filter of the intermediary d. c. circuit with the values: $L = 8mH$ and $C = 840\mu F$ ensure a continuous conduction of the *i*$_d$*(t)* current and the "smoothing" of the rectified voltage, decreasing its ripple from $r_{u(j)r} = 100(556-220)/426 = 78{,}8\%$ to

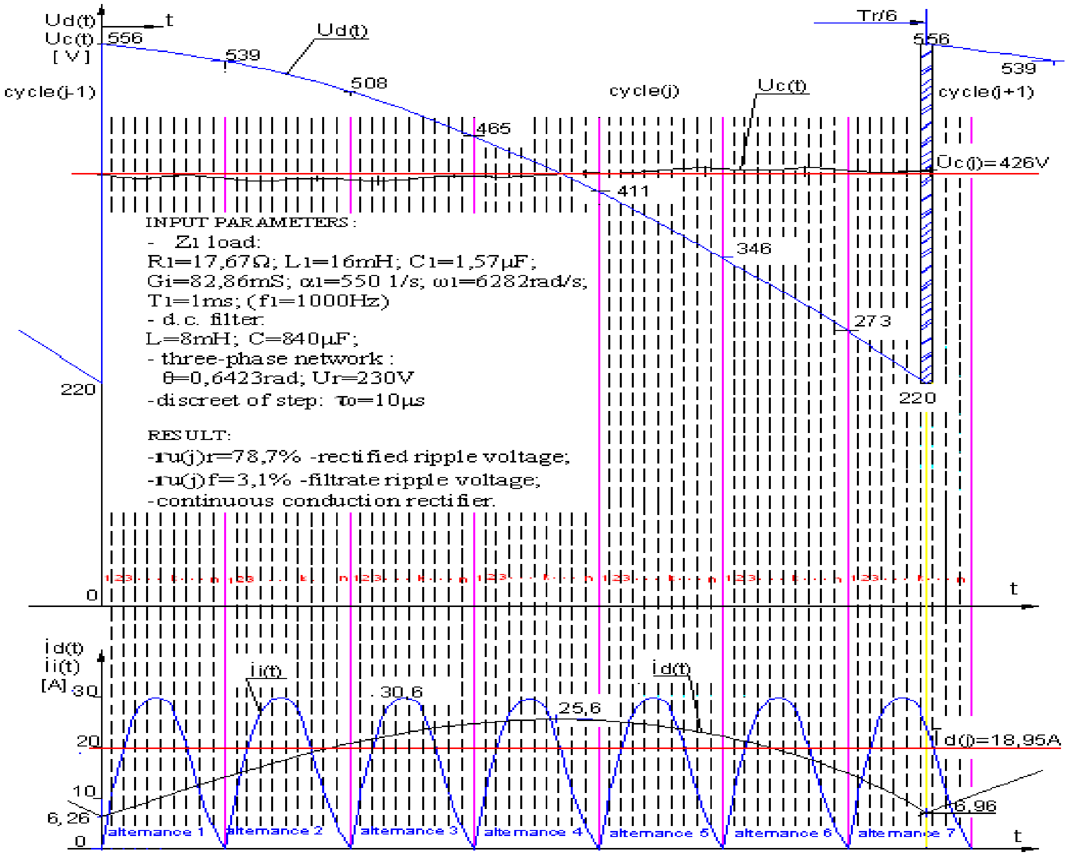


Fig.4. the wave forms of the voltages and currents from the Source-ozonizer system calculated with the <<UI-RCD>> program

$r_{u(j)f} = 100(433{,}2-420)/426 = 3{,}1\%$ The ripple $r_{u(j)f}$ and the peak of the high voltage applied on the ozonizer that has to be under 10% is transmitted, so that the filtering matches the needs of the ozonizer.

6. Conclusions

The single-phase high voltage source for the medium and high power ozone generators *(>5kW)*, supplied by a three-phase network (with a thyristorized rectifyer, completely controlled), needs a very strict electrical calculus of dimension.

The main functional exigencies that are imposed to source are:
• The inverter must function in voltage resonance with the load to maximize the efficiency of the source;
• The ripple of the filtered voltage $u_c(t)$ from the d.c. circuit must be under *10%.*

The expressions of the $i_d(t), i_c(t)$ and $u_c(t)$ with $t=[0, T_r/6]$, can be obtained by directly integrating the system's differential equations, that need restrictive conditions to help resolve them, like the invariance of some quantities (ex. $u_c(t)$=const). We obtain very hard and difficult to use calculus relations for the calculus of dimension (to see the much simpler analysis of the form wiring diagram presented in [1] cap 3.3, for example).

In this paper the solution we used is integrating the differential equations on small, infinitesimal intervals, by discretizing the $T_r/6$ period in $qn = T_r/6\tau_0$ intervals of $\tau_0 \to 0$ time (fig. 4). The solution has the following advantages:
• The calculus relations of the electrical quantities can be simplified (linearized) on the (*k*) interval of τ_0 time;
• The $i_d(t)$ and $u_c(t)$ quantities have got continuity from an *(k)* interval to the next (*k+1*), this way recurrence relations can be established;
• On any (*k*) interval the initial (instantaneous), medium and the effective values can be calculated for any electrical quantity, from which on a cycle ($T_r/6$) result the wave forms, the peak, medium and effective total values;
• The state quantities $i_1(t)$ and $u_d(t)$ that determine the system's evolution in time, can have any other periodical forms of wave, that can be defined mathematically, advisable with the condition: $f_1 > 6f_r$;
• The calculus relations are easy to implement in a BASIC language program, the flow chart of which is presented in fig.3.

The calculus program allows the evaluation of the transient or stabilized working regime (the wave form of the currents and voltages) and the calculus of the values of the electrical components of a single-phase static adjustable power source, which is supplied by a three-phase alternative voltage network.

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