ELECTRIC POWER SYSTEMS - EMC

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Summary The paper is dealing with some electromagnetic compatibility (EMC) problems of converters and inverters, which are utilized for feeding of electric machines.

1. INTRODUCTION

The importance of the electromagnetic compatibility (EMC) of all electrical products is rapidly increasing during the last decade. The environment is increasingly polluted by electromagnetic energy. The interference output into own surroundings is doubled every three years and covers a large frequency range. The possibility of the disturbances of equipments and errors becomes more serious as the consequence of the growth of the electronic circuit complexity. According to the new technical legislation and also due to economic consequences the EMC concept of all products must be strictly observed [1]. It must start with the specification of the equipment performance and must stop with the equipment installation procedures.

2. EMC AND ENVIRONMENTAL WASTE

The possible interfaces between sources and objects are shown in Fig. 1. The four basic types of coupling ways can realize these interfaces.

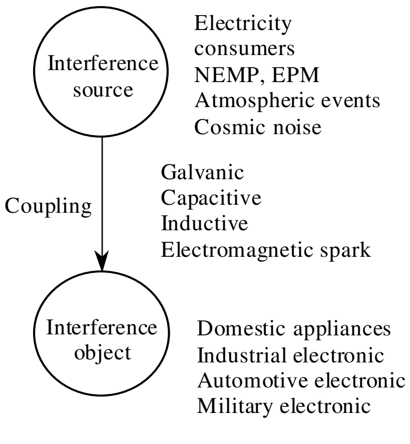

Fig. 1. Interference diagram

3. INDUCTIVE COUPLING

For the predictive investigation of the intercircuit inductive coupling we will focus our attention to the case of the two electrical loops l_1 and l_2 with the currents i_1 a i_2 and we will try to state the influence of the loop l_1 on loop l_2 as it is shown in Figs. 2 and Fig. 3.

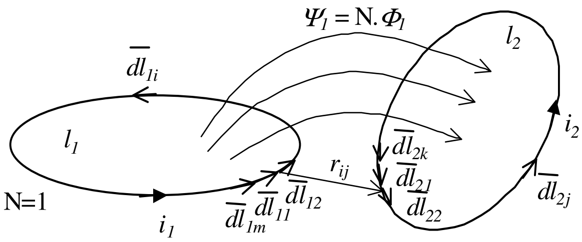

Fig. 2. The investigated loops

If we know the geometrical dimensions of the investigated loops - Fig. 3 and we want to state their mutual inductive coupling, then we can use the next relation (1) for the induced voltage, which is based on the 3D Cartesian coordinate system. Measured results are shown in Fig. 4.

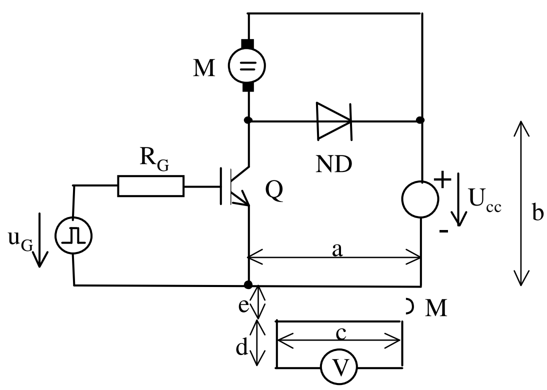

Fig. 3. The investigated circuits

$$u_i = -\frac{di}{dt}.\sum_{i=1}^{M}\sum_{j=1}^{k}\frac{\mu}{4\pi}\frac{(A_{x2i}-A_{x1i}).(B_{x2j}-B_{x1j})+(A_{y2i}-A_{y1i}).(B_{y2j}-B_{y1j})+(A_{z2i}-A_{z1i}).(B_{z2j}-B_{z1j})}{\sqrt{C+D+E}} \quad (1)$$

where

$$C=\left(\left(\mathrm{B}_{x1j}+\frac{\left|\mathrm{B}_{x2j}-\mathrm{B}_{x1j}\right|}{2}\right)-\left(\mathrm{A}_{x1i}+\frac{\left|\mathrm{A}_{x2i}-\mathrm{A}_{x1i}\right|}{2}\right)\right)^2$$

$$D=\left(\left(\mathrm{B}_{y1j}+\frac{\left|\mathrm{B}_{y2j}-\mathrm{B}_{y1j}\right|}{2}\right)-\left(\mathrm{A}_{y1i}+\frac{\left|\mathrm{A}_{y2i}-\mathrm{A}_{y1i}\right|}{2}\right)\right)^2$$

$$E=\left(\left(\mathrm{B}_{z1j}+\frac{\left|\mathrm{B}_{z2j}-\mathrm{B}_{z1j}\right|}{2}\right)-\left(\mathrm{A}_{z1i}+\frac{\left|\mathrm{A}_{z2i}-\mathrm{A}_{z1i}\right|}{2}\right)\right)^2$$

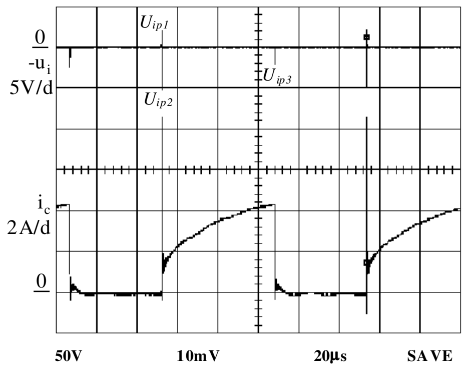

Fig. 4. The measured voltage -u_i and current i_C

4. CAPACITIVE COUPLING

Capacitive coupling is typical for galvanically separated circuit nodes, between which exists mutual influence by individual intensity vectors $\overline{E}_i$ of electro static field, Fig. 5.

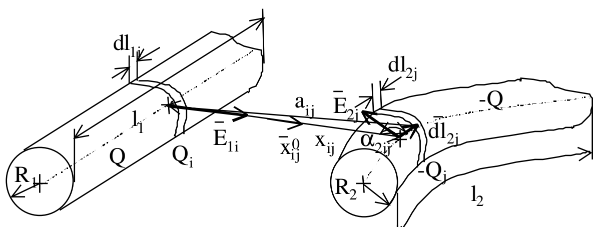

Fig. 5. Capacitive coupling

In such case the influence value is given by rising or decreasing slope of potential in described nodes, electrode area dimensions, space dielectric property and wire geometrical ordering in described nodes. Searched value of the parasitic capacitance is possible to determine as equation (2).

$$C_{12}=\frac{2\pi\varepsilon}{\left(\sum_{i=1}^{m}\frac{F}{dl_{1i}}+\sum_{j=1}^{n}\frac{G}{dl_{2j}}\right)} \tag{2}$$

where

$$F=\ln\frac{x_{ij}-R_2}{R_1}.\sqrt{\left(1-\left(\frac{x_{ij}^2+\left(\frac{dl_{2j}}{2}\right)^2-a_{ij}^2}{x_{ij}.dl_{2j}}\right)^2\right)}$$

$$G=\ln\frac{x_{ji}-R_2}{R_1}.\sqrt{\left(1-\left(\frac{x_{ji}^2+\left(\frac{dl_{1i}}{2}\right)^2-a_{ji}^2}{x_{ji}.dl_{1i}}\right)^2\right)}$$

Circuit investigation was done according the Fig. 6. Measured results are shown in Figs. 7 and 8.

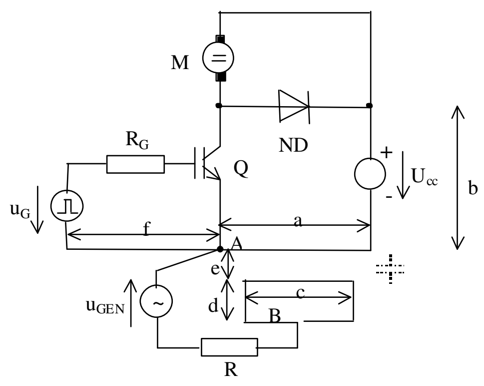

Fig. 6. Investigated circuit

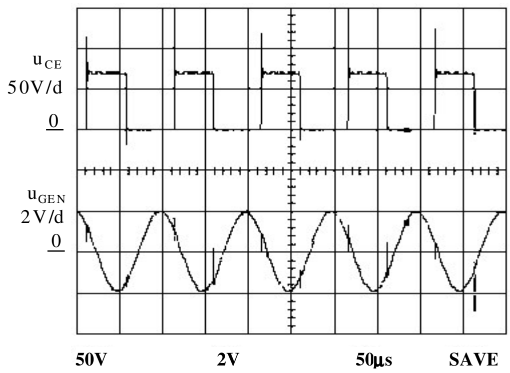

Fig. 7. Measured results for f = 10 kHz

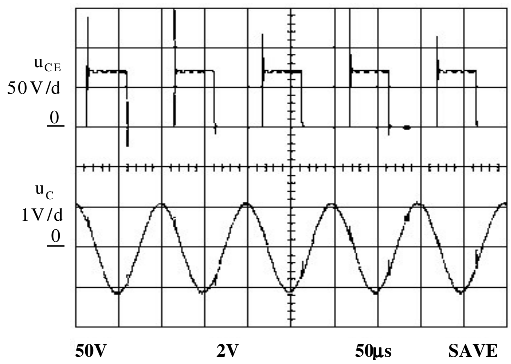

Fig. 8. Measured results for f = 10 kHz

5. GALVANIC COUPLING

The problem of galvanic coupling deals with individual electric equipment or their part's interconnections in such a way, that minimum one or (in some cases as for example feeding net) more common conductors, interconnecting these equipments and so mutual influence is generated. In the following step, we will try to obtain imagination about the galvanic coupling existence of only two interacting circuits. For the simplification of the analytic investigation it is suitable to suppose, that pure resistors create the loads in both the galvanic connected circuits and that the circuits are in steady states and they are supplied from DC voltage sources as it is shown in figure Fig. 9 and Fig. 10.

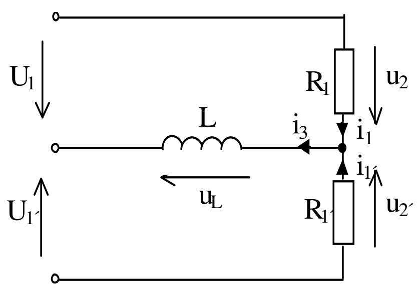

Fig. 9. The investigated circuit

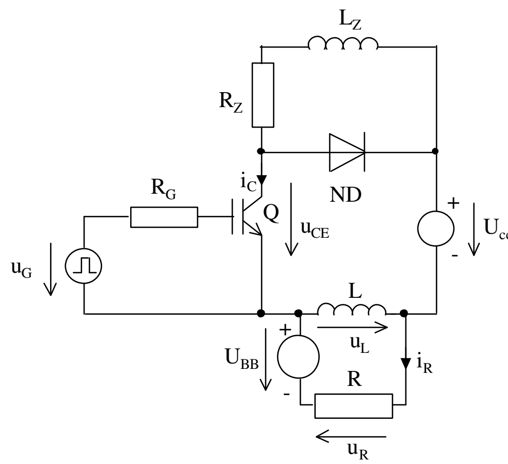

Fig. 10. The connection of the measured circuit

Let the voltage source $U_{1'}$ is switching, then the voltage u_2 can reach the values:

$$u_2 = U_1 - u_L = U_1 - L.\frac{di_3}{dt} = U_1 + U_{1'}.\frac{R_1}{(R_1 + R_{1'})}.e^M \tag{3}$$

$$u_2 = U_1 - u_L = U_1 - L.\frac{di_3}{dt} = U_1 - U_{1'}.\frac{R_1}{(R_1 + R_{1'})}.e^M \tag{4}$$

where

$$M = -\frac{R_1 R_{1'}}{L(R_1 + R_{1'})}.t$$

depending on switching the slope polarity. Measured results are displayed in figure Fig. 11.

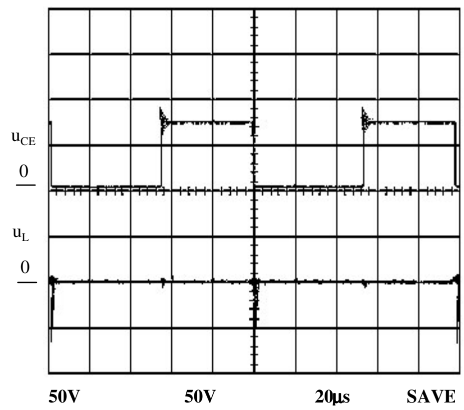

Fig. 11. Results obtained by measurement

6. ELECTROMAGNETIC COUPLING

Electromagnetic coupling is typical for the galvanically separated electrical circuits between of which exist the exchange of the electromagnetic energy. Such energy is then presented in the form of radiated and absorbed power. The investigated circuit is shown in Fig. 12.

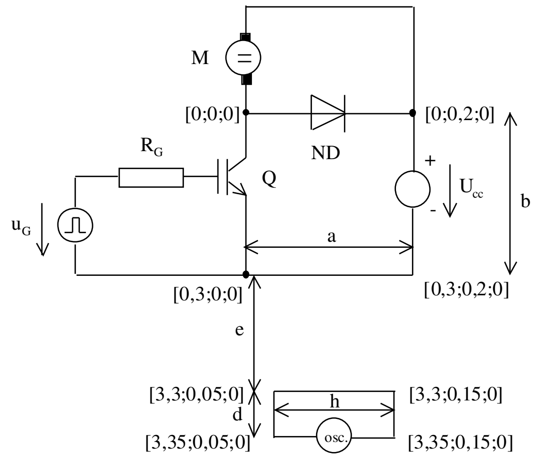

Fig. 12. Scheme of the investigated circuit

A part of the induced voltage u_i, caused by the magnetic field energy, is given as:

$$u_{imag} = -\mu_0 . S . \frac{\sqrt{N} - \sqrt{O}}{\Delta t} \qquad (5)$$

where

$$N = H_x^2(t + \Delta t) + H_y^2(t + \Delta t) + H_z^2(t + \Delta t)$$

$$O = H_x^2(t) + H_y^2(t) + H_z^2(t)$$

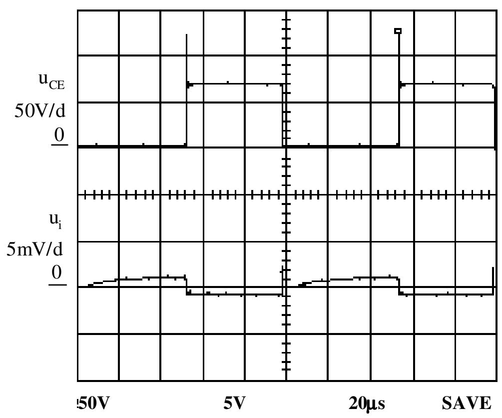

Fig. 13. Measured induced voltage u_i

A part of the induced voltage u_i, caused by the electric field energy, is given as:

$$\begin{aligned} u_{ielek} = & \left(E_{xA}(t + \Delta t') - E_{xA}(t)\right).d + \\ & + \left(E_{xC}(t + \Delta t') - E_{xC}(t)\right).d + \\ & + \left(E_{yA}(t + \Delta t'') - E_{yA}(t)\right).h + \\ & + \left(E_{yC}(t + \Delta t'') - E_{yC}(t)\right).h \end{aligned} \qquad (6)$$

where $\Delta t' = d/c$, $\Delta t'' = h/c$. Measured induced voltage is shown in Fig. 13.

7. CONCLUSION

The measured results are confirming the correctness of the above-mentioned formulas obtained by the mathematical analyses and so can be used for predictive EMC investigation.

Acknowledgement

The paper has been prepared by the support of the Slovak grant project No. 1/1084/2004.

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