HYSTERESIS AS THE SAKE OF NON-LINEARITY ELEMENTS IN THE POWER SYSTEM AND ITS INFLUENCE ON THE CREATION OF FERRORESONANCE

Branislav Bátora
Doctoral Degree Programme (2), FEEC BUT
E-mail: branislav.batora@phd..feec.vutbr.cz

Supervised by: Petr Toman
E-mail: toman@feec.vutbr.cz

ABSTRACT

This article deals with the issue of district problems non-linearity elements of the power systems as sakes on the creation of ferroresonance. Paper analyze influence hysteresis on non-linearity of elements on concrete application on coil with iron core. Result study is point out influence of non-linearity elements on the creation of ferroresonance.

1. INTRODUCTION

The effort to decrease the power dissipation in the energetic system stemming from increasing ecological and economical requirements is the reason of the growing frequency of occurrence of various incidental phenomena. It is important to consider the system as a whole, so it is necessary to take into account the fact that lowering the power dissipation will lead to absorption in the system. However, that results in increasing and lengthening the system's response to any change, and therefore also to the character of transient phenomena. In the electric power system these are usually a short-term increase or decrease in voltage. It can also happen that as a result of a change in the system, the voltage will increase permanently, which might have a destructive effect on most electrical appliances.

2. NON-LINEAR ELEMENTS

An especially dangerous kind of overvoltage is the overvoltage occurring as a result of resonance in a part of the system. The electric power system can be regarded as an electrical circuit, which includes to a great extent non-linear inductances and capacitances. The main factors in the non-linearity of inductance are especially transformers, iron core inductors and other elements of an electric power system. Long power lines, restraining condensers, on the other hand, introduce non-linearity to the capacitance of the circuit. As a result of the presence of the above mentioned non-linearities, resonance occurs in case specific conditions are fulfilled. The conditions for the creation of ferroresonance are shown in this fig.1:

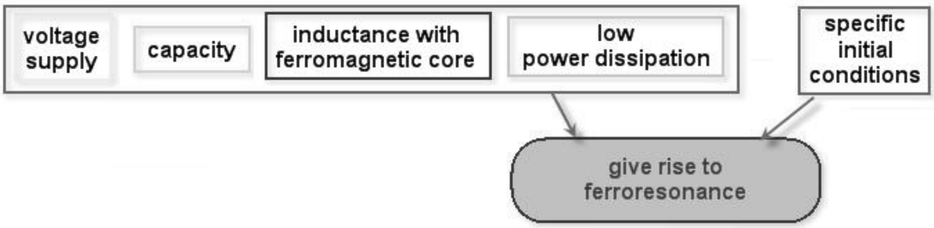

Fig.1.The conditions for the creation ferroresonance

The resonance caused by non-linear inductance, such as an iron coil inductor, is called ferroresonance. The overvoltage caused by this ferroresonance is called ferroresonance overvoltage.

3. DEFORMATION OF ELECTRICAL VALUES IN CIRCUITS WITH ELEMENTS WITH AN IRON CORE

When connecting a magnetic circuit field coil with an iron core, with N number of coils, to a source of harmonic voltage

$$u(t) = U_m \sin \omega t \qquad (1)$$

The magnetic flux arising in the magnetic circuit induces in the field coil harmonic voltage of the same value

$$u_i(t) = N \frac{d\phi(i)}{dt} = U_m \sin \omega t \qquad (2)$$

Instantaneous value of the magnetic flux is

$$\phi(i) = \int \frac{U_m}{N} \sin(\omega t) dt = -\frac{U_m}{\omega N} \cos \omega t = \frac{U_m}{\omega N} \sin\left(\omega t - \frac{\pi}{2}\right) \qquad (3)$$

As the previous equation shows, the progress of the magnetic flux is harmonic, but lags behind the voltage by a quarter of the period. The magnetizing current, whose progress is shown in fig.2, corresponds with the harmonic magnetic flux.

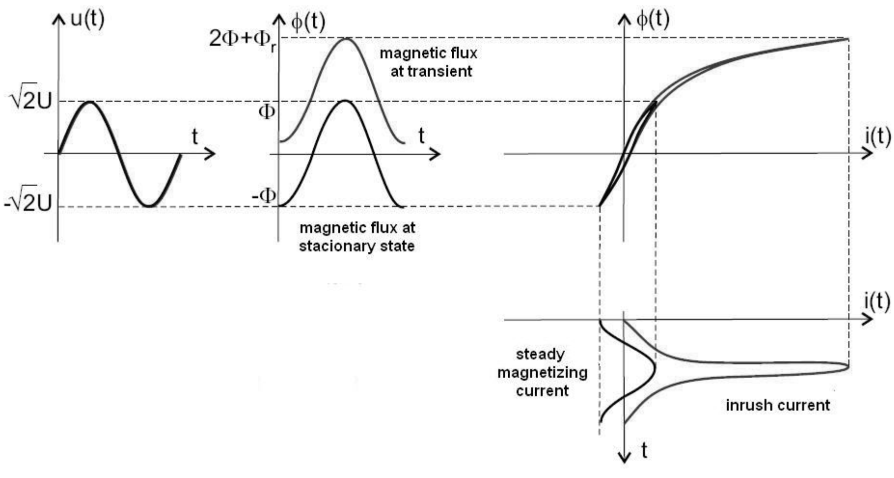

Fig.2. Time behaviour magnetizing current

The biggest influences on the non-linearity in an iron core are shown in this scheme:

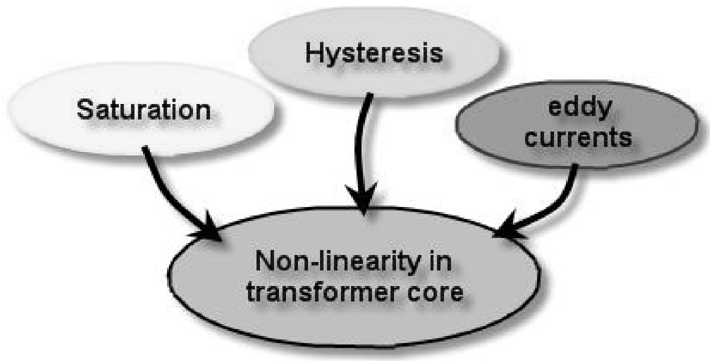

Fig.3.Influences on the non-linearity

4. HYSTERESIS

Manifests itself in magnetic circuits by hysteresis losses. Hysteresis losses are caused by warming of the coil core by the passage of an alternating current and are proportional to the area of the hysteresis loop. When describing the non-linear characteristics with regard to hysteresis, it is necessary to take into account the dependence of the current not only on the magnetic flux but also on its derivation. Therefore it stands that:

$$\phi = \frac{u - R \cdot i(\phi, \phi')}{N} \tag{4}$$

$$i(\phi, \phi') = i_a(\phi) + i_H(\phi, \phi') \tag{5}$$

The current component $i_a(\phi)$ is so called backbone of a hysteresis loop. The component $i_H\left(\phi, \frac{d\phi}{dt}\right)$ represents so called small hysteresis loop and is limited by the width of the main hysteresis loop $-i_h < i_H\left(\phi, \frac{d\phi}{dt}\right) < i_h$. To simplify the mathematical model we assume, that the small hysteresis loop is a mere horizontal segment and it stands that:

$$i_H(\phi, \phi') = i_h \operatorname{sgn}(\phi') \tag{6}$$

Since the sgn function is a continuous function we can adjust the equation as follows:

$$f(\phi') = \phi' + i_h \operatorname{sgn}(\phi') = \frac{u - R \cdot i_a(\phi)}{N} \tag{7}$$

The resulting state equation:

$$\phi' = f^{-1}\left(\frac{u - R \cdot i_a(\phi)}{N}\right) = \frac{R}{N} \cdot dz\left(\pm i_h, \frac{u}{R} - i_a(\phi)\right) \tag{8}$$

where $dz(\pm i_h, x)$ is the dead zone within the range $\pm i_h$. The current of the small hystersis loop i_H corresponds with that signal component which did not participate in the magnetic flux integration, as it was withheld in the dead zone, i.e.

$$i_H(\phi') = \frac{u}{R} - i_a(\phi) - dz\left(\pm i_h, \frac{u}{R} - i_a(\phi)\right) \qquad (9)$$

It is worth noticing that the flux extremes Φ are flat (during the change of polarity the flux goes through the hystersis via the small hystersis loop). The value of the generated voltage $u_{ind} = N \cdot d\Phi/dt$ is therefore in this area zero, and the voltage u is registered only on the resistance, i.e. $u = i \cdot R$.

State scheme (in SIMULINK):

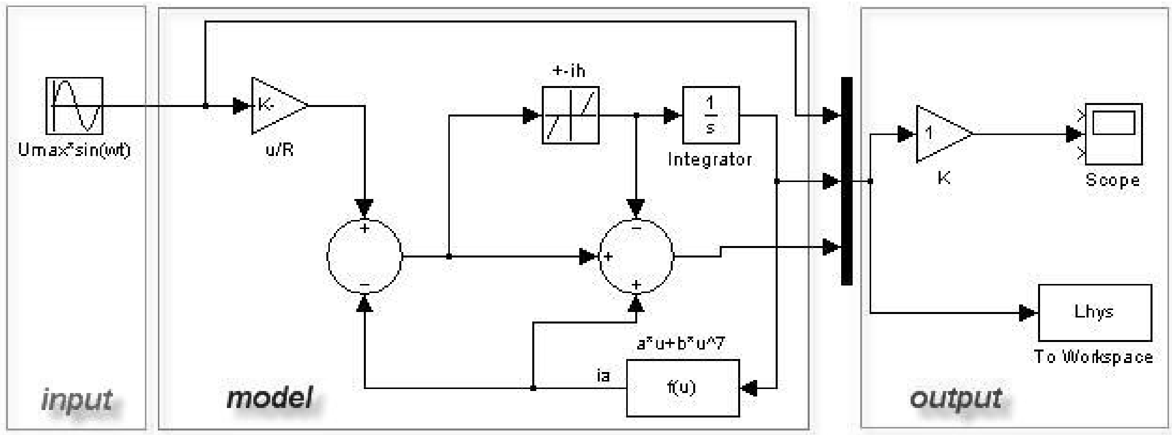

Fig.4. State scheme of equation n.9 from program SIMULINK

The results of the simulation with zero input condition for the magnetic flux are shown in the following graph1 (without hysteresis) and graph2 (with hysteresis).

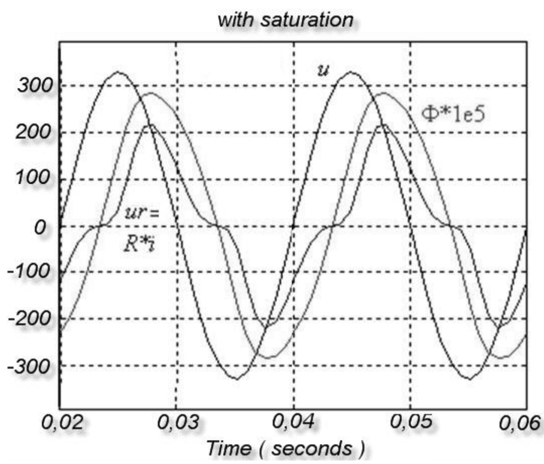

Fig.5. Graph without hysteresis

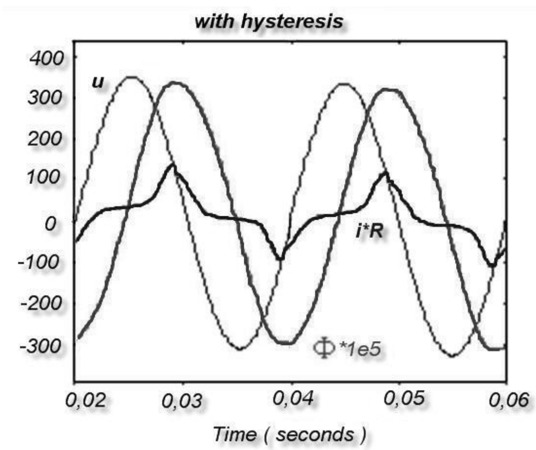

Fig. 6. Graph with hysteresis

5. CONCLUSIONS

In the age, when economic and ecologic views of electric power systems are increasingly topical, we are trying to minimize costs both of production and transfer of electrical energy. By lowering the power dissipation in the course of electrical energy transfer, the system becomes more sensitive to the consequences of various transient phenomena. Therefore it is important to minimize their impact as much as possible by using various filters and surge diverters.

ACKNOWLEDGMENTS

The paper includes the solution results of the Min-istry of Education, Youth and Sport research project No MSM 0021630516.

REFERENCES

[1] KARBAN, P. Výpočty a simulace v programech Matlab a Simulink, Brno: Computer Press, 2006

[2] Toman, P. Analýza nestandardních typů přepětí v elektroenergetických soustavách, Brno, 2004, Habilitační práce