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WHAT IS WRONG WITH THE BUDEANU´S CONCEPT OF POWER EQUATION

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Abstract: In this paper is developed powerful techniques for defining power theory under nonsinusoidal conditions. The new method is based on a scalar product of time varying electrical quantities and physical properties of real circuit elements. It consists of subdividing the quantities into active and reactive components. The method permits to determine the power theory unambiguously.

Keywords: power theory, nonsinusoidal condition, physical law, scalar product.

1 Introduction

The Budeanu´s definitions of reactive and distortion power in circuits with nonsinusoidal waveforms have been spread in electrical engineering, despite some objections, for almost 75 years. The objections have concerned mainly with the question of whether these powers should be defined in the frequency domain and whether they can be measured as defined. Unfortunately, the main drawbacks of these definitions have not been noticed. Namely, the Budeanu´s reactive and distortion powers do not possess any attributes which might be related to the power phenomena in the circuit. Moreover, their values do not provide any information which could enable the design of compensating circuits. Also the distortion power value does not provide any information about waveform distortion. Therefore, Budeanu´s concept has led the power theory of circuits with nonsinusoidal waveforms into a blind alley. The commonly used Budeanu´s definition of reactive power [1] is

$$Q_B = \sum_{n=1}^{\infty} U_n I_n \sin \varphi_n , \qquad (1)$$

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where U_n, I_n are rms values, and φ_n, the phase angle of voltage and currents n-the harmonics. Budeanu introduced a new quantity

$$D_B = \sqrt{S^2 - P^2 - Q_B^2} \tag{2}$$

called the distortion power.

These powers has been criticised as lacking physical meaning. A series of alternative definitions has been suggested [2]. All of them, however, are based on Fourier´s analysis of current and voltage waveforms.

2 Power analysis by means of physical laws

The state of a circuit is known completely it the voltages across all terminals and the currents are known. In this case we can calculate all powers. For example in series circuit model of the electromagnetic phenomenon all instantaneous voltages

$$u = u_R + u_L + u_D = Ri + L\frac{\mathrm{d}\,i}{\mathrm{d}\,t} + D\int_0^t i \cdot \mathrm{d}\xi = Ri + Li' + Di^x$$

and their rms values are unambiguously stated by physical laws

$$U^2 = U_R^2 + U_L^2 + U_D^2 - 2\mathrm{U}_\mathrm{L}^2 U_D^2 \cos\varepsilon$$

and are shown in a voltage vector diagram in Fig. 1.

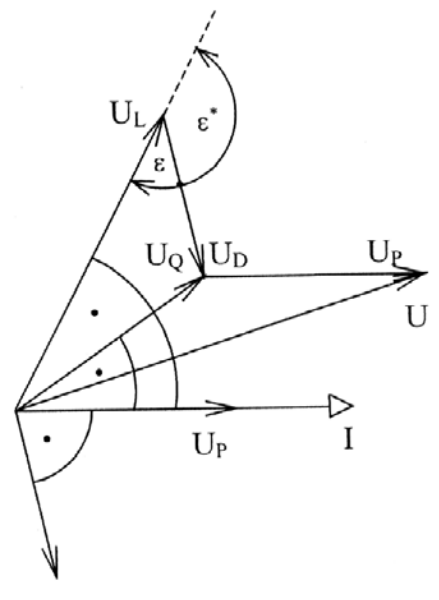

Fig. 1 The voltage vector diagram

Now the powers are calculated by multiplications of voltages and current.

2.1 Power theory by means of physical laws

The instantaneous voltages and the instantaneous current are unambiguously represented by their rms values. The instantaneous powers are unambiguously stated by the multiplications of the instantaneous voltages and the instantaneous current

$$p = ui = (u_R + u_L + u_D)i,$$

by the multiplications their rms values are unambiguously represented the powers

$$P^2 = U^2 I^2 = \left(U_R^2 + U_L^2 + U_D^2 - 2U_L U_D \cos\varepsilon\right) I^2,$$

where

$$p = ui, \qquad P = UI$$
$$p_R = p_P = Rii = u_p i, \quad P_P = RII = U_P I$$
$$p_L = Li'i = u_L i, \qquad P_L = LI'I = U_L I$$
$$p_D = Di^x i = u_D i, \qquad P_D = DI^x I = U_D I$$
$$p_Q = u_Q i, \qquad P_Q = U_Q I.$$

The instantaneous power p is the algebraic sum of the instantaneous active power p_P and the instantaneous reactive power p_Q, whereas (appearance) power P is the geometric (vector) sum of the active power P_P and the reactive power P_Q

$$p = p_P + p_Q, \qquad P^2 = P_P^2 + P_Q^2.$$

2.1.1 Power vector diagram

The power vector diagram of the electromagnetic phenomenon we obtain by means of the replacement of the letters U by P in the voltage vector diagram which is shown in Fig. 1.

The power vector diagram of the series circuit model is identical to the power vector diagram of the dual parallel circuit model. Its current vector diagram we obtain by means of the replacement of the letters U by I.

3 Conclusion

The powers are defined consistently with the physical laws: Ohm´s law, induction law, equation of continuity, Kirchhoff´s laws and the mathematical definition of the scalar product time varying quantities. This method is an effective tool for the circuit analysis under nonsinusoidal conditions.

The inductor reactive powers are defined by the induction law, the capacitor reactive powers are defined by the equation of continuity and the reactive powers have been determined in terms of the inductor reactive power and the capacitor reactive power as shown above. It means that the others formulae of the reactive powers are not consistently defined by physical laws.

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