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THE CONSERVATION OF ACTIVE POWERS IN CIRCUITS THAT OPERATE IN UNBALANCED AND NON SINUSOIDAL REGIMES

BY

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Abstract. In this paper is considered an electrical network which works in an unbalanced and non sinusoidal regime. Are presented the cause of appearance of the non sinusoidal regime, the harmonics source, how behaves each circuit element, the way in which the active powers flow and their balance. It is also shown, the way in which the neutral conductor connection influences the currents flow in network.

Key words: non sinusoidal regime; active powers in non sinusoidal regime; unbalanced and non sinusoidal regime.

1. Introduction

The appearance of a non sinusoidal regime in an electrical circuit is due to the existence of a parametric or nonlinear element in that circuit (Rosman & Savin, 1974). These circuit elements are component of many types of electrical consumers.

The appearance of the unbalanced condition is due to uneven distribution of the electrical consumers on the three phases (Varvara & Georgescu, 2007). The uneven loading of the three phases is dependent on time,

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because consumers can be connected and disconnected at different moments of time (Varvara & Georgescu, 2007).

In unbalanced operating regimes, the potential of the neutral point of a star winding transformer is not anymore equal with zero. The value of this voltage depends on the way the neutral conductor is connected. The type of connection determines the way in which flows the current on zero sequence in the network and the additional active power losses in the distribution line. The penetration in the distribution lines of the current of zero sequence is the main cause of a possible harmonic interference in neighbouring telephone systems. The connection at the ground can be realised through a reactance or a resistance.

2. Active Powers Flow in Electrical Networks Operating in an Unbalanced and Non-Sinusoidal Regime

It is considered a low voltage urban distribution network. On the low voltage side of a transformer, the voltages are symmetrical and sinusoidal. We can replace it with a generator (*G*) that supplies symmetrical voltages of sinusoidal shapes. The impedances of the three phase distribution line (*L*) are considered identical. Because on each phase are connected a different number of loads, the equivalent impedances on the three phases are non identical. The unbalanced and linear consumer (*UL*) has the neutral connected to the ground through an impedance, which in particular cases can be a resistance, a reactance or can take the zero value.

The converters are the main nonlinear elements of circuit at medium voltage and are responsible for the appearance of the harmonics in the whole network. At low voltage, the so called, fluorescent lighting and the color TVs must be considered, as consumers with an important harmonic contribution. The equivalent nonlinear consumer is noted (*NC*).

The unbalanced operating regime can be analysed with the help of the symmetrical components, the non-symmetrical signals being decomposed in three symmetrical signals of the following sequences: positive (subscript +), negative (subscript –) and zero (subscript 0). Thus, the unbalanced regime becomes a superposition of three balanced operating regimes that are analysed with specific methods.

The flow of the active powers in a network that contains nonlinear consumers and unbalanced and linear consumers is shown in Fig. 1, all the explanations being given below.

The equivalent generator of infinite power (*G*) supplies active power (P_{G1+}) only on first harmonic (1), that corresponds to 50 Hz and only on positive sequence (+). The distribution line (*L*) receives some of this power, P_{L1+}, the nonlinear consumer (*NC*) receives P_{NC1+} and the unbalanced and linear consumer (UL), receives P_{UL1+}.

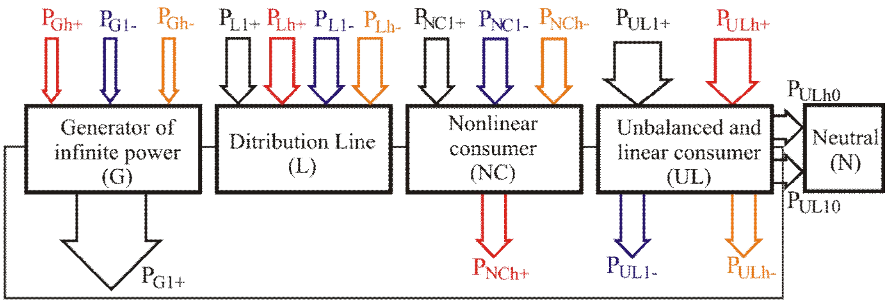

Fig. 1 – The flow of the active powers in a network that contains nonlinear consumers and unbalanced and linear consumers.

The balance of active powers on first harmonic and on positive sequence is:

$$P_{G1+} = P_{L1+} + P_{NC1+} + P_{UL1+}. \quad (1)$$

Regarding the magnitude of some of the powers described above, because the installed power of the unbalanced and linear consumer is much bigger than the others from the network, the following relation is valid:

$$P_{UL1+} >> P_{NC1+} + P_{L1+}. \quad (2)$$

The nonlinear consumer converts a part of the active power received from generator on first harmonic and on positive sequence, P_{NC1+}, in harmonic powers (subscript h) of positive sequence, P_{NCh+} and injects them in the network.

The balance of active powers is:

$$P_{NCh+} = P_{Gh+} + P_{Lh+} + P_{ULh+}. \quad (3)$$

Regarding the powers on harmonics, the unbalanced and linear consumer receives the biggest part of the powers injected by the nonlinear consumer. The generator is much less affected by this injection:

$$P_{ULh+} >> P_{Lh+} + P_{Gh+}. \quad (4)$$

The unbalanced and linear consumer converts a part of the active power on first harmonic and on positive sequence, P_{UL1+}, in active power on first harmonic and on negative sequence (–), P_{UL1-} , and in active power on first harmonic and on zero sequence (0), P_{UL10}. The first is injected towards the other elements of circuit, (G, L, NC) and the second toward the neutral (N).

The balance of active powers on first harmonic and on negative sequence, respectively on zero sequence is:

$$P_{UL1-} = P_{G1-} + P_{L1-} + P_{NC1-}, \;\; P_{UL10} = P_{N10}. \quad (5)$$

Regarding the magnitude of some of the powers described above, because the generator is considered of infinite power, the following relation is valid:

$$P_{G1-} << P_{L1-} + P_{NC1-}, \quad (6)$$

Also, the unbalanced and linear consumer converts a part of the active power on harmonics and on positive sequence, P_{ULh+}, in active powers on harmonics and on negative sequence P_{ULh-} and in active powers on harmonics and on zero sequence, P_{ULh0}.

The first are injected towards the other elements of circuit, (*G*, *L*, *NC*) and the second, towards the neutral (*N*).

The balance of active powers on harmonics and on negative sequence, respectively on zero sequence is:

$$P_{ULh-} = P_{Gh-} + P_{Lh-} + P_{NCh-}, \; P_{ULh0} = P_{Nh0}. \quad (7)$$

Because the generator is considered of infinite power, most of the powers on harmonics and on negative sequence flow towards the distribution line and, especially, towards the nonlinear consumer:

$$P_{Gh-} << P_{Lh-} + P_{NCh-}. \quad (8)$$

At the generator there is an active power on first harmonic and on positive sequence delivered by the generator itself, P_{G1+}, an active power on harmonics and on positive sequence received from the nonlinear consumer, P_{Gh+}, an active power on first harmonic and on negative sequence received from the unbalanced and linear consumer, P_{G1-}, and an active power on harmonics and on negative sequence received from the same unbalanced and linear consumer, P_{Gh-}. The first of these four powers is positive, being a generated power, much greater than the other three, which are negative, being received powers. The generator behaves as a true generator for the first power and as a receiver for the last three.

The balance of active powers at the generator is:

$$P_G = P_{G1+} + P_{Gh+} + P_{G1-} + P_{Gh-}. \quad (9)$$

At the distribution line there is an active power on first harmonic and on positive sequence, P_{L1+}, an active power on harmonics and on positive sequence, P_{Lh+}, an active power on first harmonic and on negative sequence, P_{L1-}, and an active power on harmonics and on negative sequence, P_{Lh-}. The firs power is received from generator, the second, from the nonlinear consumer and the last two, from the unbalanced and linear consumer. The distribution line behaves as a true receiver for all of the four powers.

The balance of active powers at the distribution line is:

$$P_L = P_{L1+} + P_{Lh+} + P_{L1-} + P_{Lh-}. \quad (10)$$

The line is, in this way, loaded with a supplementary power ΔP_L which represents, in fact, supplementary active power losses:

$$\Delta P_L = P_{Lh+} + P_{L1-} + P_{Lh-}. \quad (11)$$

At the nonlinear consumer there is an active power on first harmonic and on positive sequence received from the generator, P_{NC1+}, an active power on harmonics and on positive sequence generated by the nonlinear consumer itself, P_{NCh+}, an active power on first harmonic and on negative sequence received from the unbalanced and linear consumer, P_{NC1-}, and an active power on harmonics and on negative sequence received from the unbalanced and linear consumer, P_{NCh-}. The nonlinear consumer behaves as a generator for the second power and as a true receiver for the other three.

The balance of active powers at the nonlinear consumer is:

$$P_{NC} = P_{NC1+} + P_{NCh+} + P_{NC1-} + P_{NCh-} . \quad (12)$$

At the unbalanced and linear consumer there is an active power on first harmonic and on positive sequence, P_{UL1+}, an active power on harmonics and on positive sequence, P_{ULh+}, an active power on first harmonic and on negative sequence P_{UL1-} and an active power on harmonics and on negative sequence, P_{ULh-}, the last two powers being generated by the unbalanced and linear consumer itself. The unbalanced and linear consumer behaves as a generator for the third and fourth powers and as a true receiver for the first and second.

The balance of active powers at the unbalanced and linear consumer is:

$$P_{UL} = P_{UL1+} + P_{ULh+} + P_{UL1-} + P_{ULh-} . \quad (13)$$

The unbalanced and linear consumer is the most affected by the non sinusoidal and unbalanced regime that appears.

Through the neutral conductor flows the active power on first harmonic and on zero sequence, P_{N10}, and the active powers on harmonics and on zero sequence, P_{Nh0}, both of them being received from the unbalanced and linear consumer. The neutral conductor behaves as a true receiver for the two powers.

The balance of active powers at the neutral conductor is:

$$P_N = P_{N10} + P_{Nh0} . \quad (14)$$

In the absence of the neutral conductor, these powers flow in the whole network.

In a medium voltage distribution network operating in a non sinusoidal regime, harmonic currents coming from different deforming elements gather, taking into account the existence of the phase shifts between these currents. The strongest harmonics in the medium voltage distribution networks are the odd ones and among them, the third one. The harmonics of order which are multiple of three flow through the neutral, when it exists. Thus, the current in the neutral conductor can be big. If we do not want to have a flow of active powers of zero sequence in the network, the existence of the neutral is essential. The penetration in the lines of distribution and transport of the electrical energy of the current of zero sequence, when the neutral is insulated, is the main cause of a possible harmonic interference in neighboring telephone networks, even when the level of the zero sequence current is low in comparison with the current of positive sequence. In the near future it is not expected to be diminished the magnitude of the harmonics of third order which are injected by the nonlinear consumers.

It is expected that the problems caused by harmonics will grow, taking into account the estimations that the battery chargers will increase in number and installed power because the future of locomotion belongs to electricity.

3. Conclusions

A balanced and linear consumer behaves, always, as a receiver for active powers.

An unbalanced and linear consumer behaves as a generator for active powers on zero and negative sequences and as a receiver for other kinds of powers.

A nonlinear consumer behaves as a generator for the active powers on harmonics and as a receptor for other kinds of powers.

In the absence of a neutral conductor, the currents of zero sequence flow in the whole network, determining the increase of the active power losses.

If the power of the generator is big, the voltage remains sinusoidal at its bars.

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CONSERVAREA PUTERILOR ACTIVE ÎN CIRCUITE CE FUNCȚIONEAZĂ ÎN REGIMURI DEZECHILIBRATE ŞI NESINUSOIDALE

(Rezumat)

În această lucrare este considerată o rețea electrică care funcționează într-un regim dezechilibrat şi nesinusoidal. Sunt prezentate cauza apariției regimului nesinusoidal, sursa de armonici, modul în care se comportă fiecare element de circuit, modul în care circulă puterile active şi bilanțul acestora. S-a arătat, de asemenea, modul în care legătura conductorului neutru influențează circulația armonicilor în rețea.