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POWER QUALITY AND STATIC CONVERTERS

- Summary -

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Paper's aim is to generate knowledge about the quality of energy, static conveters modelling, a better understanding of the problems created by the harmonics generation in the grid to provide viable solutions to eliminate the negative effects of the nonlinear consumer.

Chapter 1 is an introduction to power quality issues and presents widely electromagnetic disturbances leading to degradation of power quality.

First of all is made a short description of what the electric power does mean and the power quality term is define. The power quality has become a problem because more and more consumers are affected by voltage dips and interruptions, harmonics produced by the new equipment used in power electronics. Then detailed for each electromagnetic disturbance is presented:

- a definition of disturbances;
- sources that produce such a disturbance;
- effects they produce in on the equipment;
- solutions to improve the disturbance.

In chapter two presents harmonics genereted by static power converters.

The first part is a description of the Fourier series, which establish a mathematical relationship between time function and frequency range. Fourier series is one of three forms: trigonometric, harmonic and exponential. Both, Fourier transforms, classical Fourier transform and the discrete, provides an opportunity to examine a function or waveform in time and frequency domain.

Further on, in the two separate subsections we analyzed, harmonics genereted by ordered rectifiers and indirect static conveters.

Drive systems with DC motors and controlled rectifiers are an important source of harmonic pollution, both in terms of their spread and the harmonics genereted. Harmonics produced by static converters occur from asymetry in the building, switching times, inaccuracies in the opening instantaneous thyristor.

To determine all the influences, to simulate operation of the system at rated load for three values of the control angle (30°, 45° and 60°), obtaining waveforms for the primary and secondary currents and secondary voltage of the transformer and corresponding harmonic spectrum. To validate the results obtained from simulation, experiments were done on a drive system similar to that used in simulation schemes and were obtained waveforms show in (Fig.1).

Regarding harmonics genereted by the indirect static conveters, a special attention was done to the energetic influence of the filter from the intermediate circuit. Two cases of intermediate supply circuit were analyzed: i) from a single-phase uncontrolled rectifier and ii) from a three-phase uncontrolled rectifier. For different values of inductance and capacitance of the intermediate circuit was represented the current waveform of the primary of the transformer and the corresponding harmonic spectrum. These values have an influence on the interrrupted current regime of the rectifier.

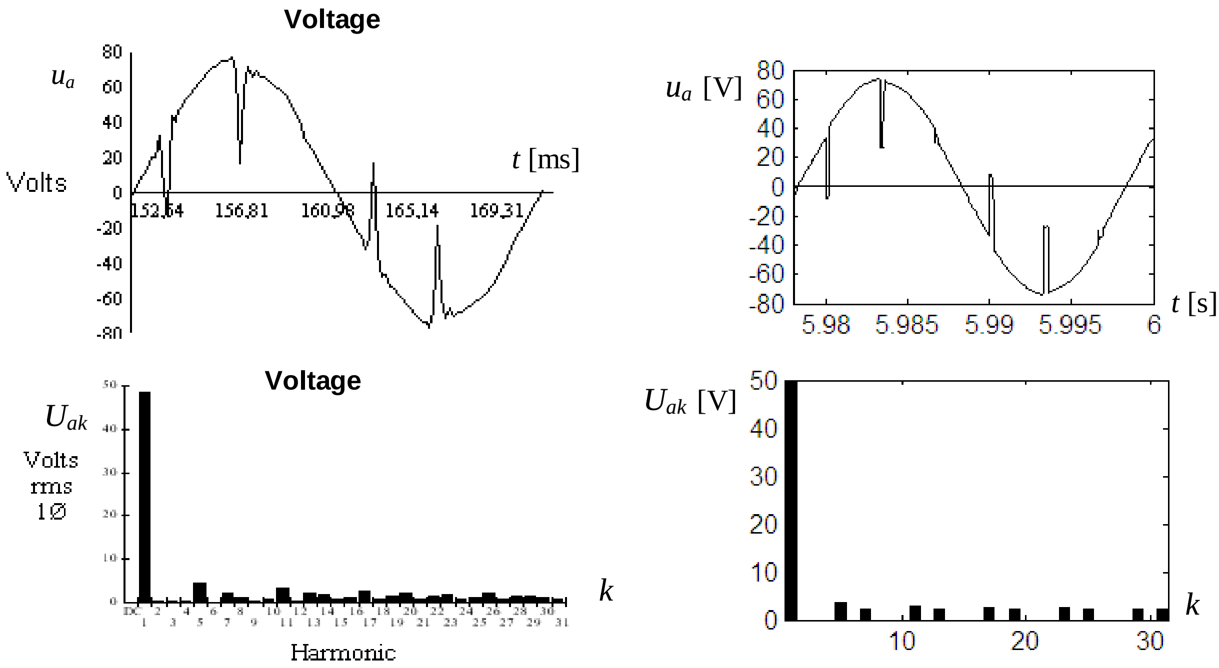


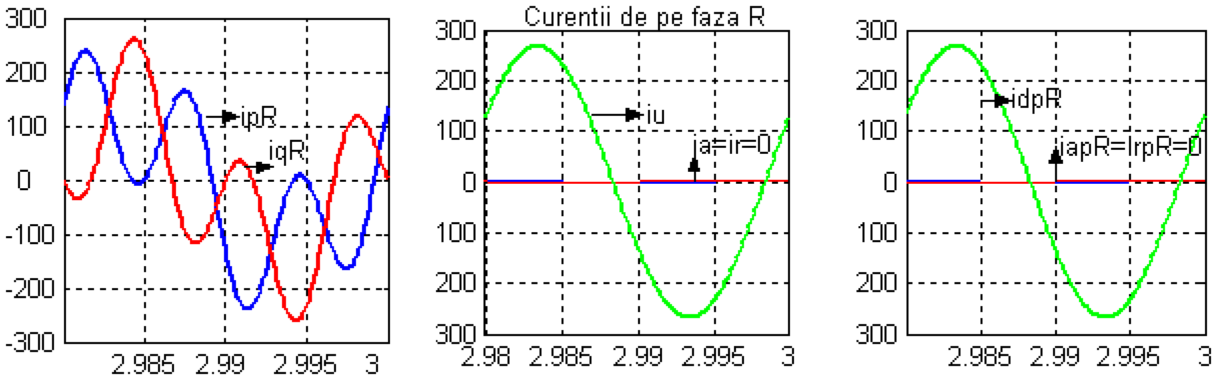
***Fig. 1** Voltage waveform of the transformer secondary and the corresponding harmonic spectrum, experimental (left) and obtained by simulation (right), to control the angle of 60^0*

Chapter 3 presents the link between power quality and power theory as a result of problems caused by harmonics in the systems. Concerns about the phenomena related to power have advanced from simple passive observation to active attempts to improve these aspects. To improve power quality and power factor using resonant filters and active filters. In international scientific circles, there is a sustained discussion on the definiton of powers under nonsinusoidal regime. In particular, it ascertains the deformed power intoduced by Budeanu in 1927. The theory of current physical components (CPC), developed by Prof. Czarnecki, although presented as a decisive and definitive definition of powers under nonsinusoidal, it has serious deficiencies of implementing the system with static converters.

The first part presents the theoretical support of the three methods namely: p-q theory, the currents'physical components and correct interpretation of the p-q theories.

Unlike the generalized theory of the instantaneous power, the main concern in developing the Current's Physical Components theory was the connection with power phenomena. Powers properties in the three phase circuit with voltages and currents sinusoidal are caused by three phenomena independende: (i) – permanent energy conversion between the power supply and load, a phenomenon associated with active power P; (ii) – presence of reactive elements, a phenomenon associated with reactive power Q; (iii) – the asymmetry current supply because of the unbalance load, phenomenon associated with the deformed power D. Instantaneous reactive power p-q theory is based only two quantities of powers, instantaneous active power p and instantaneous reactive power q, which are completely different phenomena associated with the circuit. Correct interpretation of the p-q theory defines three currents related to physical phenomena occuring in the circuit.

Based on theory and using Matlab-Simulink tool is made a comparative analysis of these methods. **Were analyzed following case studies: a)- unsymmetrical purely resistive load and voltage sinusoidal b)-sinusoidal voltage and unbalanced load; c)-nonlinear load supplied from a nonsinusoidal voltage; d)-symmetrical nonlinear load supplied from a voltage sinusoidal**. In (Fig. 2), shown waveforms of currents in the phase R, for the case when the unbalanced load is supplied from sinusoidal voltage.



a) b) c)

Fig.2 *Graphical representation of the phase currents R: a) p-q theory; b) current's physical components theory; c) correct interpretation of the theory p-q*

For this load, appear just current unbalanced because this load is active and reactive power is zero, according to CPC theory and [15]. According to the p-q theory, although P and Q are zero, active and rective currents appear (Fig. 2a), which is not correct.

Examples analyzed based on the following conclusions:

- current's physical components is successfully applied to circuits with sinusoidal voltages and currents;
- this theory gives accurate results when the unsymetrical nonlinear load is supplied from a voltage nonsinusoidal;
- CPC gives erroneous results when applied to a static converter;
- theory p-q defines two currents, which have different meanings of current active respective reactive current, gives the CPC, although the same name;
- the active component defines in [15], is the active component of load current only when the voltage is sinusoidal regardlless of type of the task.

Chapter 4 entitled „Means to compensate harmonics", presents the main methods to reduce harmonics, an increased attention being given to the active filters.

Among the various topologies of active filters presented, one that was chosen is the voltage source inverter, because it provides an optimum cost-quality ratio.

Particular attention in this chapter is given the calculation methods of the reference currents of active filter. Thus were examined four methods of calculation: Fourier method with eliminating the fundamental component in frequency domain and respective in time domain, method p-q, synchronous detection method and synchronous reference frame method. For each method analyzed using Matlab-Simulink tool was developed a calculation block of the reference currents and then this block has been integrated into a Simulink model its load was kept constant and the accuracy of the prescribed current was monitored using the value of the distortion factor value obtained in the network. On the graphs from simulation schemes can draw the following conclusions:

-both calculation methods in frequency and time domain, prescribe a current that is followed by actual current of filter;

-method which prescribe the correct current reference is Fourier method with eliminating the fundamental component, which obtained from a network THDI= 0.05 %;

Further on, it makes noticeable the compensation capacitor voltage influence on the current distortion factor obtained from the grid. For this, a Simulink model was done, which in turn have changed the distortion factor of the load and root means square current, resulting on the dependence THDI=f(Uc), in (Fig. 3).

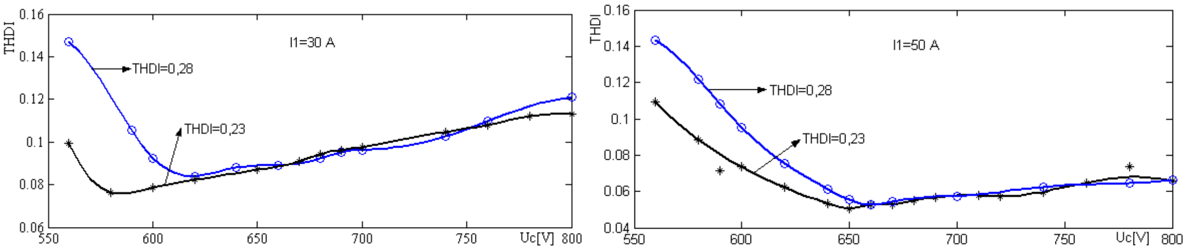


Fig. 3 *Evolution of the distortion factor depending on the capacitor voltage for two values of load current*

For graphs shown in (Fig. 3), the most important conclusion is that an optimal voltage of compensation capacitor to produce a minimum harmonic distortion factor of current network. Optimal value of the compensation voltage capacitor increases as the load increases the RMS current.

To verify the existence of an optimal value of the capacitor voltage compensation, experimental determinations was made using a nonlinear load and active filter existing in the laboratory of the Faculty of Engineering in Electromechanical Environment and Industrial Informatics. The experimental results consisted of recording waveforms of load current and the network current after the service of active filter. The examined cases are shown in Tab. 1.

Table 1. *Distorting factors of the distorsion and network current*

Uc[V]	600	625	650	675	700
THDIs[%]	110	110	110	110	110
THDI[%]	45	42,7	36,8	37,16	42
PTHD[%]	43	39,7	35	33,2	40,4

Based on experimental results, we obtain harmonic distorsion factor dependence in accordance with of compensation capacitor voltage (Fig. 4).

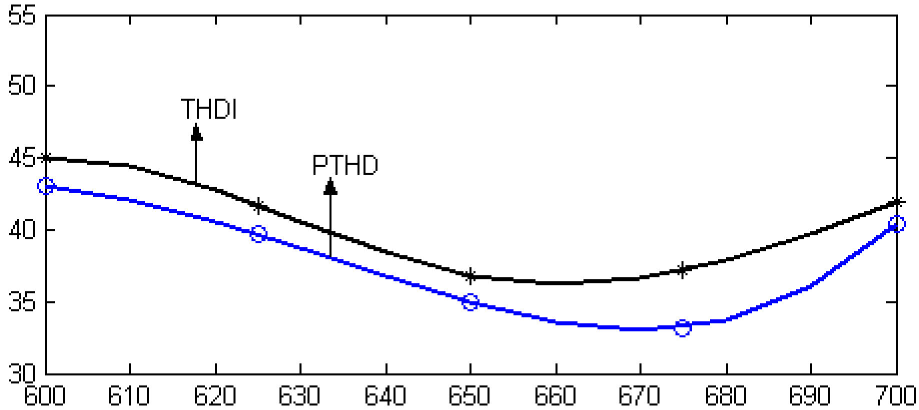


Fig. 4 *Dependence of distortion factor in accordance with of voltage on the capacitor compensation (experimental)*

Conclusions:

- there is always an optimum value of voltage on the capacitor compensation, which minimizes the distortion factor of the network current;
- for cases examined, the minimum total harmonic distortion factos is obtained for U_c=650 V, and the lowest part of harmonic distortion factor is obtaimed for U_c=675 V;
- case experimental results, the harmonic distortion factor is influenced by a family of switching frequency harmonics produced by the filter.

Author contributions refers to as appropriate processing and interpretation of existing theoretical developments, some still in the discussion of the scientific community.

A summary of the contributions is given below:

1. A synthesis of the main disturbances affecting the power quality, by emphasizing the sources, effects and existing solutions to improve the negative effects;
2. The modeling, using the Matlab-Simulink tool, of the system drive DC motor and three-phase fully controlled bridge rectifier, and it makes noticeable in this way the generated harmonics and the verification by experimental measurements, the results obtained by simulation;
3. Development of the Simulink model of the indirect PWM voltage and frequency static converter, intermediate circuit, and RLC load assembly and the analyze of the filter influence from the intermediate circuit, on the harmonics from the mains supply;
4. Implementation some case studies, comparison between phasors theory and CPC theory, the main theories of power and components under nonsinusoidal current there is in dispute in the scientific community;
5. Emphasises the limit the application of CPC theory, when load is produced by the static converters;
6. Emphasises the applicability and getting accurate results in all the cases analyzed by applying the phasors theory in a proper manner proposed in the papers written by Prof.dr.eng Alexandru Bitoleanu;
7. Making a summary, development of Simulink models and comparative study of the main methods of calculating current reference for shunt active filters;
8. Development of the Simulink model of the shunt active filter with IGBT, simulation on its operation and emphasises important features in the specialty literature;
9. An analysis based on experimental study of a shunt active filter and verify the existence of an optimum voltage prescribed by capacitor compensation.

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