New Method for Power Factor Correction with RNSIC

Constantin Filote, Calin Ciufudean, Florin Musteata, Ovidiu Chirila, and Ana-Maria Cozgarea

***Abstract*—**A new method for power factor compensation of a three-phase bridge uncontrolled rectifier with a dc filter and nonlinear load is proposed. The method is based on the Rectifier with Near Sinusoidal Currents called RNSIC, which functions as power factor compensation in a wide range of load currents. The decrease of input currents harmonics, below the limits imposed by IEEE 519/1992 and IEC 61000-3-4 international standards, allows the decrease of THD, hence the increase in real power factor. Experimental results from prototypes bench are shown to confirm the validity of proposed method.

***Keywords*—**AC/DC converter, RNSIC, Power quality, power factor, rectifier.

I. Introduction

IN a large majority of power electronics applications, the input power supply is represented by 50- or 60-Hz sine-wave ac voltage, single or three-phase, provided by the electric utility. In certain cases, we need to convert ac voltage in dc voltage. The three-phase bridge uncontrolled rectifier or three-phase rectifier with diode, called TPRD (Fig. 1), is frequently employed in a variety of applications, such as inverters and dc-to-dc converters. These rectifiers distort line currents drawn from ac mains by nonlinear loads and, thus, create serious problems to utility power.

Distorting elements of the power systems introduced by three-phase rectifier with diode are represented by non-sinusoidal current drawing or harmonic distortion, reactive power drawing, wave-form distortion of power supply by peaks of line power factor.

The notion of Power Quality (PQ) was introduced in the early 1980's, and according to IEEE Standard 1100-1999 (*IEEE Recommended Practice for Power and Grounding Electronic Equipment*), it defines „The concept of powering and grounding electronic equipment in a manner that is suitable to the operation of that equipment and compatible with the premise wiring system and other connected equipment". It correlates a series of legal norms concerning the problems of *power supply quality* and *the consumption quality*.

IEEE-519/1992 standard, in USA, and IEC 61000-3-4, in Europe impose a series of restrictions regarding the level of current harmonics in Point of Common Coupling (PCC).

The rapid development of power electronics equipments in last years, required a series of solutions and topologies aimed at the decrease of high content of current harmonics drawn from ac power systems and power factor correction.

The first alternative to reduce current harmonics is the use of classical passive filters (CPFs) that are made of LC series circuits. They have some major disadvantages, such as filtering characteristics, which are strongly affected by the source impedance, possible parallel resonance between the source and the passive filter, etc.

Other applications propose, for the reduction of other harmonics in the input current, the variant of rectifier applying current injection where, frequency of the injection current is equal to the triple of the line frequency [9], [10], [11].

Although, most papers propose various solutions for harmonic filtering, active power filter (APF) technology remains slightly inferior to passive filter (PF) [4], [7], with respect to costs and efficiency.

The passive power factor correction (PPFC) technology is more widely used due to its simplicity (without switching devices, switching losses and noise such as EMI), low cost, high reliability and simple achievement [28], [29]. In [23], it is presented a comprehensive survey of hybrid filters and a classification of the topologies proposed lately, (155 publications reference) into ten categories.

In recent years, novel topology rectifiers, such as three-phase rectifier with near sinusoidal input currents (RNSIC) [12]-[19], [25]-[27], three-phase diode rectifier with LC resonance in commercial frequency [21]-[22] and three-phase rectifier with near sinusoidal currents with dc-side C filter [28] have received increasing attention.

RNSIC was first introduced by prof. D. Alexa, in 1999 [12], and their advantages and topology were developed later [13]-[19]. As compared with TPRD with passive filter, the RNSIC has the following attractive features: sinusoidal input currents for load large variation, lower size volume and cost of the passive components. For larger load currents I_d, the amplitude of the fundamental harmonics current $I_{(1)}$ is increased, the ratio $I_{sc}/ I_{(1)}$ can be reduced by at least 20%.

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Consequently, the THD of the phase currents has to be smaller than 5 %, according to the IEEE standard 519/1992.

In this paper we show another advantage of RNSIC rectifiers which is their feature of power factor corrector for the variation in wide load range (power factor higher than 0.93).

II. THE RECTIFIER RNSIC

As power electronic systems proliferate, ac-to-dc rectifiers are playing an increasingly important role. The three-phase six-pulse full-bridge diode rectifier shown in Fig. 1 is a commonly used circuit configuration.

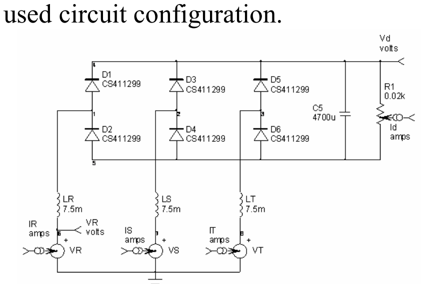


Fig. 1 Three-phase rectifier with diode (TPRD) configuration.

Fig. 2 presents the AC/DC converter, called RNSIC, which generates reduced higher order current harmonics in power systems.

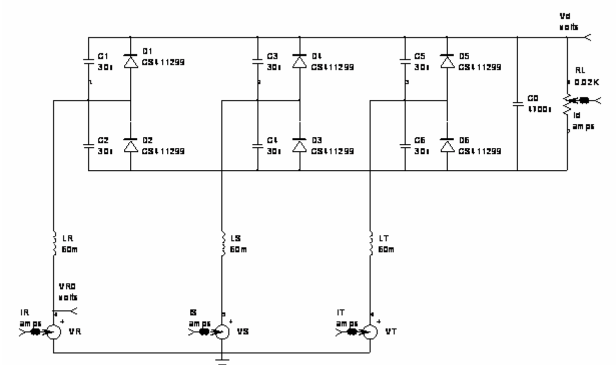


Fig. 2 Configuration of RNSIC AC/DC converter

A. RNSIC. The functioning principle

This rectifier is a traditional variant of a three-phase bridge rectifier to which some parallel diode capacitors and serial inductors are added, thus becoming an input sinusoidal current rectifier for a large range of new component values that have been set for different loads and values. The constructive solution (Fig. 2) requires the parallel mounting of some C_1-C_6 capacitors on the diode rectifier.

The capacitors C_1-C_6 have the same value C and they are DC capacitors. The inductors L_R, L_S and L_T have the same value, denoted by L_1, and they are connected on the AC side.

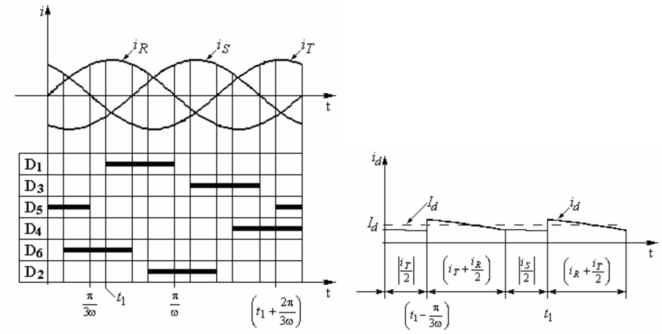
The condition that the two values of passive components has to meet is:

$$0{,}05 \le L_1 \cdot C \cdot \omega^2 \le 0{,}10 \qquad (2.1)$$

where L_1 is the AC main phase coupling inductance, C parallel diode capacitance and ω angular frequency.

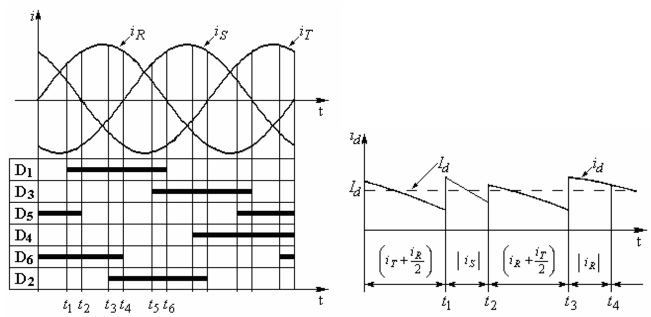
Different charging times of capacitors, which vary according to voltage, result in three distinct operating modes of the RNSIC rectifier: small current mode, medium current mode and large current mode.

In small current mode none or one diode is conducting at any time and the conduction intervals increase when the load current increases. If we note with t_1 the duration of the current charging or discharging the capacitor the small current mode is define like $2\pi/3<\omega\ t_1< \pi$. With the load current increasing rectifier changes into medium current mode ($\pi/3<\omega\ t_1< 2\pi/3$), in which one or two diodes are conducting (Fig. 3a,b). In large current mode ($0<\omega\ t_1< \pi/3$), two or three diodes conducting (Fig. 4 a,b).



a) b)

Fig. 3 Waveforms of phase currents for medium values of I_d current: (a) Waveforms of currents i_R, i_S, şi i_T ; (b) DC current i_d.



a) b)

Fig. 4 Waveforms of phase currents for large values of I_d current: (a) Waveforms of currents i_R, i_S, şi i_T ;(b) (b) DC current i_d.

Next, we shall analyze two extreme cases, during RNSIC converter functioning. In the first case, we suppose that if R_L = 0 (and so, Vd = 0), the capacitors C_1-C_6 are short-circuited and the angle $\varphi = +90^0$ is inductive. In this extreme case, the phase currents are sinusoidal and have maximum amplitude, equal to I_{max}.

In the second case, if the

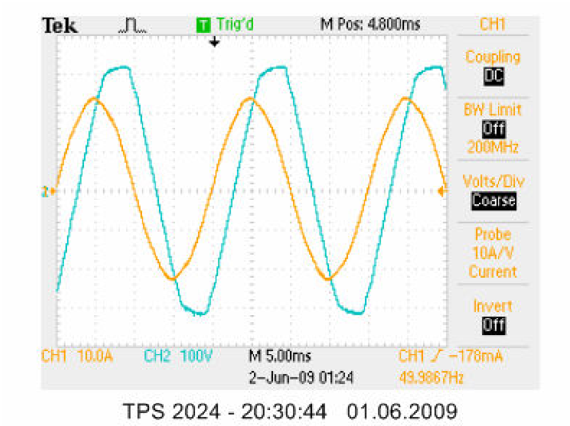
$$V_d \ge \frac{\sqrt{3}\cdot V_{m1}}{1-2\cdot L_1\cdot C\cdot \omega^2} \qquad (2.2)$$

the diodes $D_1^{'} - D_6^{'}$ do not conduct at all, and the angle φ = -90^0 is capacitive (and so is $R_L = \infty$).

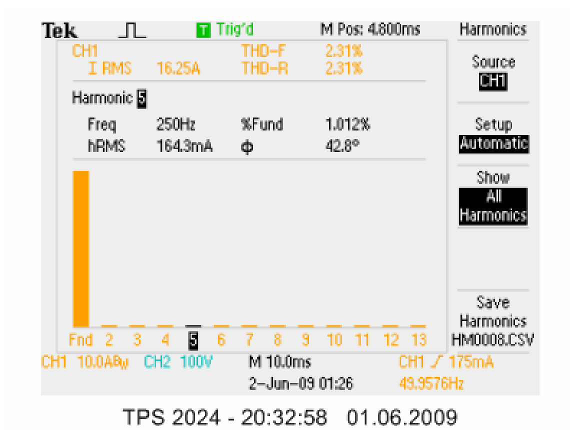
The phase currents are also sinusoidal and the amplitude has a minimum value I_{min}, referred to as holding current.

B RNSIC Experimental results

In concordance with Fig. 5 on present the waveform (a) and spectrum (b) of the I_R phase current for RNSIC rectifier.



a)



b)

Fig. 5 Waveform (a) and spectrum (b) of the I_R phase current for RNSIC rectifier.

We can observe the almost sinusoidal shape and the low harmonics content of drawing current. The ratio between the harmonic 5 and the fundamental (I_5/I_1) is 1.012%, thus smaller than 4%, which is below the limits imposed by IEEE 519/1992 and IEC 61000-3-4 international standards. Furthermore, THD is 2.31% which is below the limit of 5% settled by the same standard.

The decrease of current harmonics rate below the limits imposed by the international standards led us to the idea of using RNSIC to compensate the power factor for a wider range of load variation, respectively of load current.

III. Power Factor Theory

The concept of power factor was introduced to meet the need to quantify how efficiently a load utilizes the current that it draws from AC power system. In practice, the relative impact of the nonlinear loads (AC and DC adjustable speed drives, power rectifiers and inverters, arc furnaces, discharge lighting, saturated transformers) providing harmonics and generated losses are measured by means of power factor.

If voltages and currents may be represented by Fourier series, we can write:

$$v(t) = \sum_{h=1}^{\infty} V_h \sin(h\omega t + \alpha_h) \quad (3.1)$$

where $v(t)$ is the instantaneous voltage, V_h are the peak values of voltage harmonic h and α_h is the phase of voltage harmonic h. For the currents the Fourier series representations is:

$$i(t) = \sum_{h=1}^{\infty} I_h \sin(h\omega t + \beta_h) \quad (3.2)$$

where $i(t)$ is the instantaneous voltage, I_h are the peak values of current harmonic h and β_h is the phase of current harmonic h.

According to relations (3.1) and (3.2), we can calculate the rms voltage and current as following:

$$V_{rms} = \sqrt{\sum_{h=1}^{\infty} \frac{V^2{}_h}{2}} = \sqrt{\sum_{h=1}^{\infty} V^2{}_{hrms}} = V_{1rms}\sqrt{1 + \frac{\sum_{h=2}^{\infty} V^2{}_{hrms}}{V^2{}_{1rms}}} \quad (3.3)$$

$$I_{rms} = \sqrt{\sum_{h=1}^{\infty} \frac{I^2{}_h}{2}} = \sqrt{\sum_{h=1}^{\infty} I^2{}_{hrms}} = I_{1rms}\sqrt{1 + \frac{\sum_{h=2}^{\infty} I^2{}_{hrms}}{I^2{}_{1rms}}} \quad (3.4)$$

If we calculate the average power and apparent power, we obtain:

$$P_{avg} = \sum_{h=1}^{\infty} V_{hrms} I_{hrms} \cos(\alpha_h - \beta_h) = P_{1avg} + P_{2avg} + \dots + P_{kavg} + \dots\dots \quad (3.5)$$

$$S = V_{rms} I_{rms} = \sqrt{\sum_{h=0}^{\infty} V^2{}_h} \cdot \sqrt{\sum_{h=0}^{\infty} I^2{}_h} \quad (3.6)$$

For a certain load, the true factor has been defined as the ratio of average power to apparent power:

$$pf_{true} = \frac{P_{avg}}{S} = \frac{P_{1avg} + P_{2avg} + \dots + P_{kavg} + \dots}{V_{1rms} I_{1rms} \sqrt{1 + \frac{\sum_{h=2}^{\infty} V^2{}_h}{V^2{}_1}} \sqrt{1 + \frac{\sum_{h=2}^{\infty} I^2{}_h}{I^2{}_1}}} \quad (3.7)$$

According to [37], voltage harmonics are usually smaller that 10 % in almost all practical loads. Consequently, the contribution of these voltage harmonics to average power and apparent power calculus can be neglected in a first approximation. Taking into account these approximations, the relation (3.7) which defines the real factor becomes:

$$pf_{true} = \frac{P_{1avg}}{S} = \frac{V_{1rms} I_{1rms} \cos(\alpha_1 - \beta_1)}{V_{1rms} I_{1rms} \sqrt{1 + \frac{\sum_{h=2}^{\infty} I^2{}_h}{I^2{}_1}}} = \{\cos(\alpha_1 - \beta_1)\} \cdot \sqrt{\frac{I^2{}_1}{\sum_{h=1}^{\infty} I^2{}_h}} \quad (3.8)$$

In relation (3.8) we can recognize:

- $cos\varphi_1 = cos(\alpha_1 - \beta_1)$ is power factor at fundamental frequency (displacement power factor);
- $\sqrt{\frac{I^2_1}{\sum_{h=1}^{\infty} I^2_h}}$ is distortion power factor due to harmonic pollution.

In three-phase systems, the power factor value ($pf_{three\text{-}phase}$) differs from the value corresponding to a phase, since three-phase apparent power $S_{three\text{-}phase}$ is smaller than the algebraic sum of apparent powers of the three phases S_{phase} [38]:

$$S_{three\text{-}phase} < 3\ S_{phase} \quad (3.9)$$

Consequently, in a three-phase regime:

$$pf_{true\ three-phase} = \frac{P_{avg\ three-phase}}{S_{three-phase}} = \frac{3 \cdot P_{avg\ monophase}}{S_{three-phase}} > pf_{true\ monophase} \quad (3.10)$$

Relation 3.10 shows that, in terms of the distortions of the power supply system, it is more convenient to use a three-phase rectifier than a single-phase rectifier, since for the same power for cc, the power factor is better.

IV. Power Factor Experimental

According to the experimental data obtained from a TPRD rectifier that are presented in section II.C, and on the basis of calculus relationships of real power factor (3.8), we presented in Fig. 6 the variation of real power factor (pf_{real}) and of power factor at fundamental frequency ($cos\varphi 1$ - displacement power factor). Due to the high harmonic content, the real power factor decreases when the load current decreases.

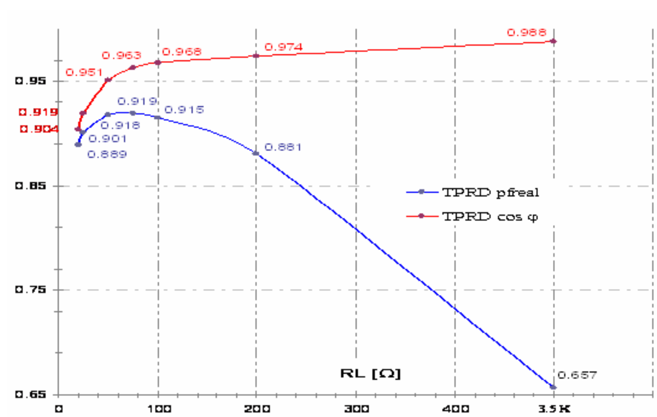


Fig. 6 The displacement power factor ($cos\varphi 1$) and real power factor variation with load (20Ω to 3,5kΩ).

On the basis of RNSIC solution presented in section II, we built an experimental bench. Several tests were carried out using different loads. The results of these experiments were presented in Table 1.

Fig. 7 shows the variation of dephasing angle between the supply voltage and system drawn current for R phase and different load values. It can be noticed that φ_1 angle changes negative values with positive values (from -90 degrees to +90 degrees). The value zero of dephasing angle implies checking the proximity of this situation in order to obtain a real power factor closer to 1.

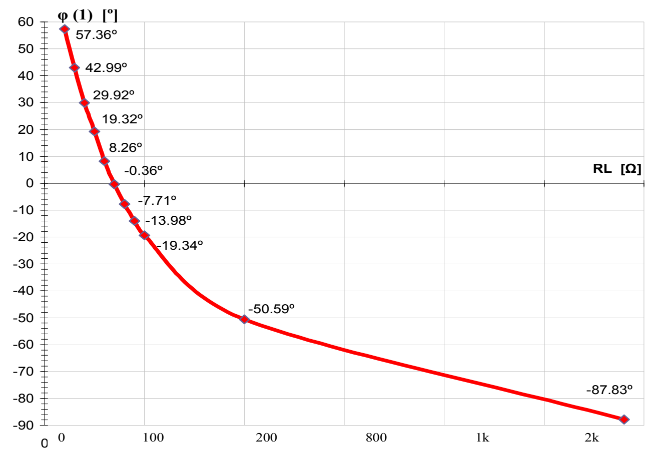


Fig. 7 Variation of fundamental $\varphi_1$dephasing depending on load resistance R_L with L = 60mH and C1-C6 = 30uF.

On the basis of calculus relationships of real power factor (3.8), we presented in Fig. 6 real power factor variation (pf_{real}) and of power factor at fundamental frequency ($cos\varphi 1$ - displacement power factor), for RNSIC rectifier.

Graphical representation leads us to the conclusion that for load values between 47Ω and 105Ω, the RNSIC rectifier behaves like a power factor compensator. Here, the power factor value exceeds 0.93, which does not require special measures to compensate it.

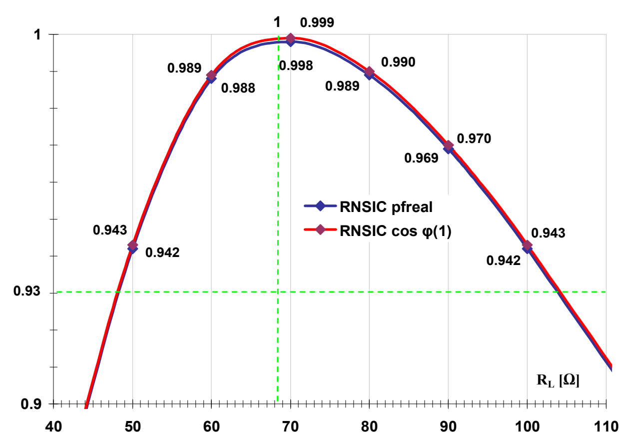


Fig. 8 Variation of fundamental $\varphi_1$dephasing depending on load resistance R_L with L = 60mH and C1-C6 = 30uF.

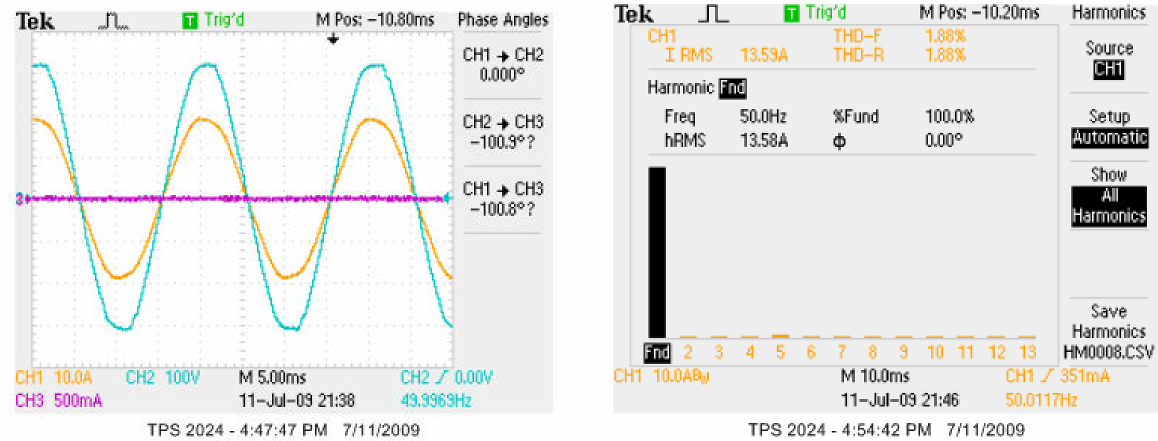


Fig. 9 Waveform (a) and spectrum (b) of the I_R phase current for RNSIC rectifier in power factor correction (PFC) regime.

I. Conclusion

The RNSIC rectifiers solution, use for AC-DC conversion presents the following advantages:

- RNSIC drawn current harmonics 5 and 7 (I_5 and I_7) decrease below the value imposed by IEEE 519 (SUA) and IEC 61000-3 (UE) standards – smaller than 4%;

-total rate of system drawn current harmonics (THD) decreases below the values imposed by IEEE standards – smaller than 5%;

- the fundamental of the drawn current (I_1) increases;

- the mean voltage of direct current V_d increases – an increase of minimum 20%;

- it compensates the power factor in a wide range of load variation, respectively of load current.

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References

[1] N. Mohan, T. Undeland and W. Robbins, *Power electronics – Converters, applications and design*, John Wiley & Sons INC., 1995, pp. 200-248.

[2] M. Kazmierkowski, R. Krishnan and F. Blaabjerg, *Control in power electronics. Selected problems,* Academic Press, 2002, pp. 89-208.

[3] B.K. Bose, *Power Electronics and Motion Drives: Advances and Trends*, ELSEVIER, 2006.

[4] H. Akagi, E.H. Watanabe, M. Aredes, *Instantaneous Power Theory and Applications to Power Conditioning*, IEEE Press, Series on Power Engineering, New Jersey: John Wiley & Sons, 2007, pp. 4-5.

[5] F. Blaabjerg, A. Consoli, J.A. Ferreira, "The Future of Electronics Power Processing and Conversion", *IEEE Trans. Industry Applications*, vol. 41(1), 2005, pp. 3-8.

[6] H. Akagi, "Trends in Active Power Conditioners", *IEEE Trans. Power Electronics*, 1994, 9, pp. 263-268.

[7] P. Pejović, P. Bozović and D. Shmilovitz, "Low-harmonics, three-phase rectifier that applies current injection and a passive resistance emulator", *IEEE Power Electronics Letters,* vol. 3, pp. 96-100, Sep. 2005.

[8] P. Pejocić and Z. Janda, "An analysis of three-phase low harmonic rectifiers applying the third-harmonic current injection", *IEEE Trans. Power Electronics,* vol. 14, no. 3, pp. 397-407, may 1999.

[9] N. Vasquez, H. Rodriguez, C. Hernandez, E. Rodríguez and J. Arau, "Three-phase rectifier with active current injection and high efficiency", *IEEE Trans. Industrial Electronics*, vol.56, no.1, pp.110-119,Jan. 2009.

[10] D. Alexa, "Combined filtering system consisting of passive filter with capacitors in parallel with diodes and low-power inverter", *IEE Proc. Power Applications,* vol. 146, no.1, 1999, pp. 88-94.

[11] D. Alexa, "Three-phase rectifier with almost sinusoidal input current", *Electronics Letters*, 2001, vol. 37, no.19, pp. 1148–1149.

[12] D. Alexa and A. Sirbu, "Optimized combined harmonics filtering system", *IEEE Trans. Industrial Electronics,* vol. 48, no.6, pp. 1210-1218, Dec. 2001.

[13] D. Alexa; A. Sirbu, D. Dobrea, "An analysis of three-phase rectifiers with near sinusoidal input currents", *IEEE Trans. Industrial Electronics,* 2004, vol. 51, pp. 884-891, Aug. 2004.

[14] D. Alexa, A. Sirbu, D. Dobrea, T. Goras, "Topologies of three-phase rectifiers with near sinusoidal input currents", *IEE Proc. Electrical Power Applications*, 2004, vol. 151, no. 6, pp. 673-678, Nov. 2004.

[15] D. Alexa, A. Sirbu and A. Lazar, "Three-phase rectifier with near sinusoidal input currents and capacitors connected on the AC side", *IEEE Trans. Industrial Electronics,* vol. 53, no. 5, pp. 1612-1620, Oct. 2006.

[16] D. Alexa, T.C. Goraş, A. Sirbu, I.V. Pletea, C. Filote, F. Ionescu, "An Analysis of the Two-Quadrant Convertor with RNSIC", *IET Power Electronics*, 2008, Vol. 1, No. 2, ISSN 1755-4535, pp. 224–234.

[17] D. Alexa, A. Sirbu, I.V. Pletea, C. Filote, R. Chiper, "Variants of rectifiers with Near Sinusoidal Input Currents-A Comparative Analysis with the Conventional Diode Rectifier", *IET Power Electronics,* 2010, to be published.

[18] K. Matsui, K. Ohtsuka, I. Yamamoto and Y. Yao, "A power factor correction with LC resonanace in commercial frequency", in *Proc. PCC 2002*, Osaka, 2002, pp. 1238-1244.

[19] I. Yamamoto, K. Ohtsuka, K. Matsui and Y. Yao, "A novel three-phase diode rectifier with LC resonance in commercial frequency", in *Proc. IECON'01*, 2001, pp. 1350-1356.

[20] B. Singh, V. Verma, A. Chandra and K. Al-Haddad, "Hybrid filters for power quality improvement", *IEE Proc.-Gener. Transm. Distrib.,* vol. 152, no. 3, may 2005, pp. 365-378.

[21] C. Filote, C. Ciufudean, A. Graur, A.M. Cozgarea, D. Amarandei, C. Petrescu, "Robust-Adaptive Flux observer in High Performance Vector Control in Induction Motors", *SPEEDAM*, Ischia, 2008, ISBN: 978-1-4244-1664-6, pp. 1097-1102.

[22] C. Filote, C. Ciufudean, A-M Cozgarea, "A Comparative Analysis of Total Harmonic Distortion", in *Proc. 13th European Conference on Power Electronics and Applications (EPE'09)*, Barcelona, Spain, 08-10 September 2009, IEEE Catalog Number CFP 09850-CDR, pp. 1-6.

[23] C. Filote, C. Ciufudean, A.M. Cozgarea, "An Analysis of Rectifier with Near Sinusoidal Current", in *Proc. 2th IEEE IES International*

Conference on Clean Electrical Power, Renewable Energy Resources Impact (ICCEP'2009), Capri, Italia, 9-11 June 2009, pp. 580-584, .

[24] C. Filote, C. Ciufudean, D. Amarandei, A.M.Cozgarea, "A New Real Method of the Instantaneous Active and Reactive Power Calculus", in *Proc. of The 26th IASTED International Conference Applied Simulation and Modelling (ASM 2007)*, 29-31 August 2007, Palma de Mallorca, Spain, pp.283-287.

[25] Y. Luo, Z. Chen, Y. Zhu and Y. Qiu, "Three-phase rectifier with near-sinusoidal input currents and capacitors parallel connected with the upper diodes", in *Proc. IPEMC*, 2009, pp. 1697-1702.

[26] Z. Chen, Y. Luo, Y. Zhu and G. Shen, "Analysis and design of three-phase rectifier with near-sinusoidal input currents', in *Proc. IPEMC*, 2009, pp. 1703-1 – 1703-7.

[27] Z. Chen, Y. Luo, Y. Zhu and S. Wang, "Optimal design method of three-phase rectifier with near-sinusoidal input currents", in *Proc. APEC*, 2010, pp. 1627-1632.

[28] Z. Chen, Y. Luo and Y. Zhu, "Topological research and comparison of low harmonic input three-phase rectifier with passive auxiliary circuit", in *Proc. APEC*, 2010, pp. 1616-1621.

[29] *IEEE Recommended Practices and Requirements for Harmonics Control in Electrical Power Systems*, IEEE Standard 519-1992;

[30] *Electromagnetic Compatibility (EMC) Part 4-30: Testing and Measuring Techniques-Power Quality Measurement Methods*, IEC Standard 61000-4-30, Jan. 1997.

[31] I.V. Pletea, M. Pletea, D. Alexa, N. Lucanu, "Simulations and Analysis and Operating Regime as Rectifier with Power Factor Correction of Two - Quadrant Converter with RNSIC", *Advances in Electrical and Computer Engineering,* vol. 9, no. 3, 2009, pp. 18-21.

[32] E. C. Bobric, G. Cartina, G. Grigoras**, "**Clustering Techniques in Load Profile Analysis for Distribution Stations", *Advances in Electrical and Computer Engineering,* vol. 9, no. 1, 2009, pp. 63-66.

[33] M. Rata, G. Rata, D. Milici, I. Graur, "An Efficient Solution of the Step-down Converter for Students Teaching", *Electronics and Electrical Engineering Journal*, 2009, no. 3(91), pp. 77-80.

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