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A Comparative Study between Classical Three Phase Rectifier Configuration with Passive Filters and Converter Configurations with Small Harmonic Contents Having Capacitors on the AC Side

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Abstract – A comparative study between three power converter configurations has been made: three-phase, six-pulse, full bridge diode rectifier, RNSIC-2 and ARNSIC-2. The study is focused in the harmonic currents contents, cost, size, and safe functionality.
Keywords: : power electronics, converter, harmonic current contents

I. INTRODUCTION

In any power conversion process , a small power loss and hence a high energy efficiency is important because of two reasons: the cost of the wasted energy and the difficulty in removing the heat generated due to dissipated energy, Other important considerations are reductions in size, weight , and cost [2].

Most power electronics applications use inexpensive rectifiers with diodes to convert the input ac into dc in an uncontrolled manner[2]-[4]. Using diodes, the power flows only from the utility ac side to the dc side. A majority of the power electronics applications such as switching dc power supplies, ac motor drives, use these uncontrolled rectifiers. In order to assure a small ripple for dc output voltage, a large capacitor is connected as a filter on the dc side. These rectifiers draw highly distorted current from the utility grid. The produced harmonics are causing higher heating losses in the transformers which convert power in the industrial environment and also affect emergency generators, AC or DC machines.

This problem regarding electrical environment is a serious concern and Europe and United States have proposed and recommended standards as IEC 1000 and IEEE 519-1992. These standards have become a common requirement for most electrical and electronic equipment producers in order to limit the harmonic content of the current drawn from the power line [14].

The three-phase, six-pulse, full bridge diode rectifier shown in Fig. 1(a) is a commonly used circuit configuration. Using passive filters the requirement IEEE 519 is accomplished.

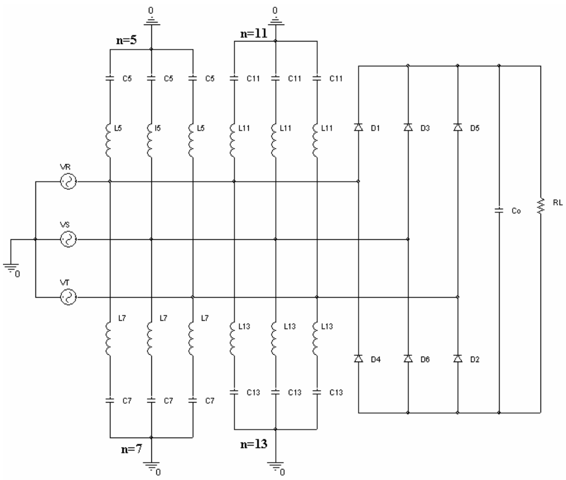

Fig. 1: Classic uncontrolled rectifier configuration with passive filters

The magnitudes of the harmonic components $I_{(n)}$ of the phase current can be determined in terms of the fundamental frequency component $I_{(1)}$ as $I_{(n)} = I_{(1)}/n$. The resonant filters condition is given by (1):

$$L_{(n)}C_{(n)}(n\omega)^2 = 1 \quad (1)$$

where n is the harmonic order : n= 5,7,11,13....

According with [15] the configuration with passive filters is economical and can be implemented in large size but, some of the limitations are:

- Instable with the operating conditions (with varying loads and utility's source impedance);

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- The parallel resonance between the system and filter;
- The aging, deterioration, and temperature can increase the designed tolerance
- To control total demand distortion the design may require increasing the size, etc.

II. RNSIC-2 AND ARNSIC-2 CONVERTER CONFIGURATIONS

In [10]-[13], two topologies of RNSIC (Rectifier with Near Sinusoidal Input Currents) converters that improve the waveform of the phase currents drawn from the utility grid have been proposed. These converters have the advantage that their functionality is not disturbed by the current or voltage harmonics, the resonance problems being avoided. A RNSIC configuration, named RNSIC-2 (the capacitors are on the AC side), is shown in Fig.2.

In order to maintain almost sinusoidal phase input currents i_R, i_S, i_T for the configuration from Fig. 2, the inductors and capacitors values must fulfill the following condition [10],[13]:

$$0.05 \le LC\omega^2 \le 0.1 \qquad (2)$$

The configuration RNSIC-2 converter is designed for rated power given by:

$$P_{dr} = V_{dr} I_{dr} \qquad (3)$$

This converter configuration has the advantage of almost sinusoidal input currents and may provide a rectified voltage V_d with 15-25% greater than the classical uncontrolled three-phase rectifier.

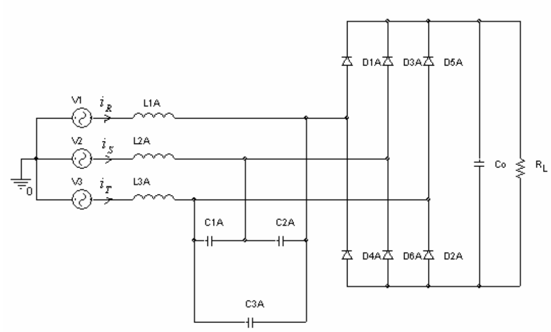


Fig. 2 : RNSIC-2 configuration

The main disadvantage of the design is that the fifth current harmonic is increasing with the load.

A new configuration using two RNSIC-2 converters connected in parallel shown in Fig. 3., named Asymmetrically RNSIC-2 (ARNSIC-2) which can be used for high and medium power has been proposed in [1]. The converters are dimensioned to work at $P_{dr}/2$.

Fundamental harmonic input currents on the same phase of the utility grid (e.g.: $i_{RA(1)}$ and $i_{RB(1)}$) are having a phase displacement angle variation between them, $\Delta\varphi = \varphi_M - \varphi_N$, at a rated operating point, consigned between 30° and 40°.

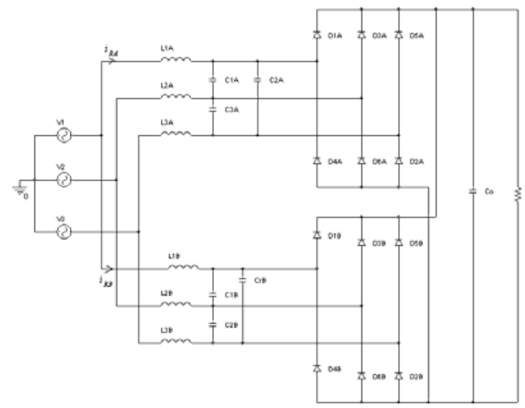


Fig. 3 : ARNSIC-2 configuration

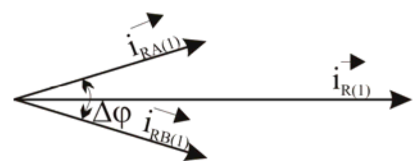


Fig.4. Phase displacement angle

The above two RNSIC-2 converters (fig. 3) can be designed to possess two different behaviors with respect to the utility grid if proper values of the inductances are chosen:

- Inductive-resistive behavior for RNSIC-2A $L_{1A} = 2(L_1 + \Delta L_1)$;
- Capacitive-resistive behavior for RNSIC-2B $L_{1B} = 2(L_1 - \Delta L_1)$.

To reduce the fifth current harmonic drawn from the utility grid the $\Delta\varphi$ must be maintained almost constant. In order to obtain the intended values for φ_M and φ_N the ΔL_1 magnitude will be chosen between 0.1 and 0.2 of L_1. Thus, the effective current that will flow through the capacitors will be radically reduced. The THD% has a good behavior with the load variation as it will be shown in the simulation results.

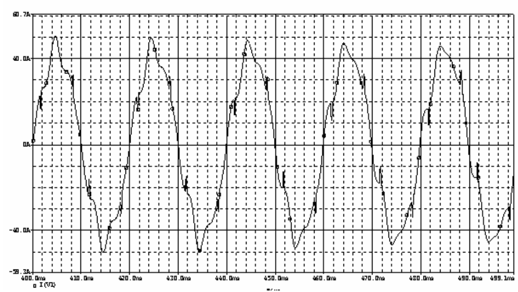
III. CLASSIC AND NEW CONVERTER PARAMETERS COMPARISON

A comparative study of classical rectifier with passive filters, RNSIC-2 and asymmetrical RNSIC-2 configurations and performances has been made using ORCAD environment.

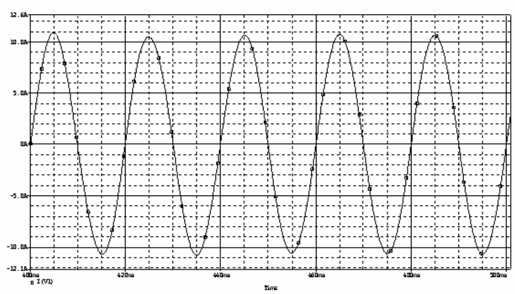
For comparison were used the following values: V_m =311V, f=50Hz, C_0 =4000μF, and also:

- For classical rectifier with passive filters: according with (1) for 5th, 7th ,9th and 11th harmonics;
- For RNSIC-2: L=20mH, C=30 μF;
- For ARNSIC-2: L_A=45mH, C_A=11 μF, L_B=35mH, C_B=8μF,

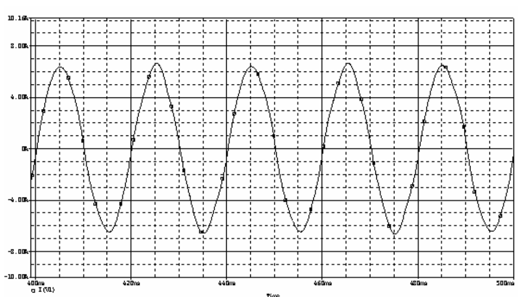
In fig 5 are shown the waveforms for phase current i_R for the converter configurations discussed. It is obviously that for the case when passive filters are used, the sinusoidal waveform of the input phase current i_R is strongly affected by the current harmonics. For RNSIC-2 and ARNSIC-2 it can be seen that the waveforms are practically sinusoidal.



(a)



(b)



(c)

Fig. 5: Phase input current i_R : (a)with passive filters;(b) RNSIC-2; (c) ARNSIC-2

The output rectified voltage is smaller for RNSIC-2 and ARNSIC-2 converter configurations with 15%-25% (fig. 6).

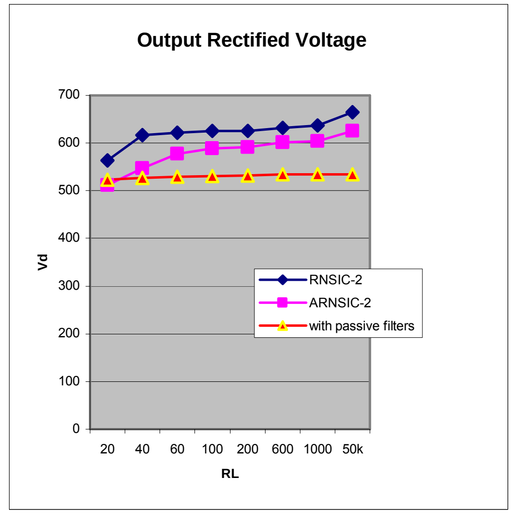


Fig. 6

The power installed in the capacitors and inductances is drastically reduced (fig. 7) especially for asymmetrical converter. The reduction of the power installed in the reactive elements for ARNSIC-2 as compared with RNSIC-2 is about 15%-20%. This means a very important reduction in size of the converter.

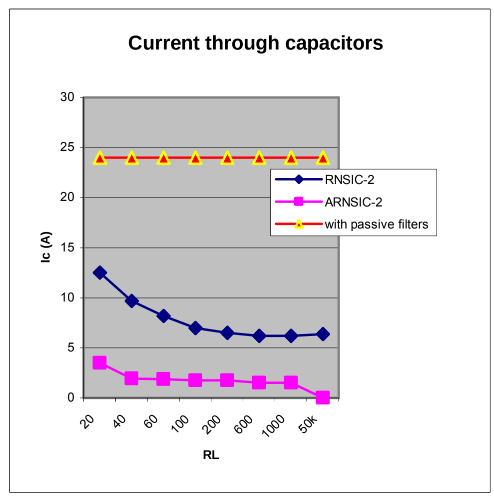


Fig.7

The amount of distortion in the voltage or current waveform (here in the input current) is quantified by means of an index called total harmonic distortion (THD%). For the configuration with passive filters, it can be seen that for small values of the load , the THD% is having unacceptable values. For the new converter configurations on the entire variation range of the load, the THD% factor for the phase input currents i_R, i_S and i_T is maintained at acceptable values, according to the IEEE standards 519 /1992. The value of the phase-shift $\Delta\varphi$, mentioned above, ensures an important reduction of the 5th order harmonic in the power grid (this being the most important harmonic in the RNSIC converters, See fig. 9).

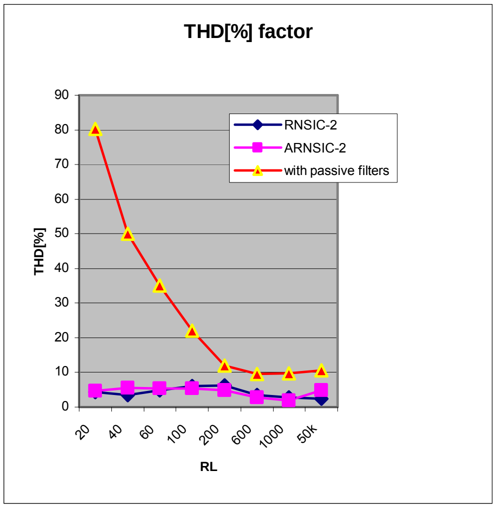


Fig. 8

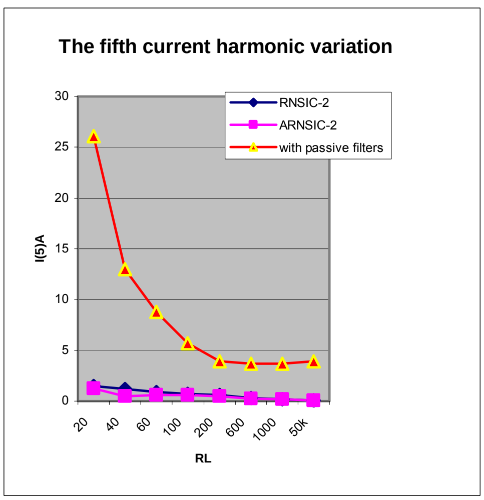


Fig. 9

IV. CONCLUSIONS

A comparison between 2 new converter configurations and a classical converter configuration with passive filters has been made.

According with the simulation results it can be concluded that choosing a configuration with passive filters the problems regarding the quality of the input phase current is diminished. The cost, size are also a problem. As compared with this configuration, for small output power it can be used RNSIC-2 configuration, and, for high and medium power is recommended ARNSIC-2 configurations. Both of its can provide a smaller output rectified voltage, a small harmonic current contents (the input phase currents are practically sinusoidal), a reduction in size of the reactive elements, and a safe functionality.

REFERENCES

[1] R. Chiper, D. Alexa, T.C. Goras, I.V.Pletea, I.M.Pletea, A.Alexandrescu: "An Analysis of Asymmetrical RNSIC Converter with Capacitor on the AC Side for High and Medium Power", ISSCS 2007, vol.2, pp.537-560, Iasi, Romania.

[2] N. Mohan, T. Undeland and W. Robbins, "POWER ELECTRONICS- Converters, Applications and Design", John Wiley & Sons Inc., 1995.

[3] B. K. Bose, "Power Electronics–A Technology Review", *Proceedings of IEEE*, vol. 80, no. 8, 1992, pp.1303–1334.

[4] M.K. Kazmierkowski, R. Krishnan and F. Blaabjerg, "CONTROL IN POWER ELECTRONICS. SELECTED PROBLEMS", Academic Press, 2002.

[5] D. Alexa, "Combined Filtering System Consisting of Passive Filter with Capacitors in Parallel with Diodes and Low–Power Inverter", *IEE Proceedings on Electric Power Applications*, vol.146, no.1, 1999, pp.88-94.

[6] J. Arrilaga and N. Watson, POWER SYSTEM HARMONICS, 2nd ed., New York, Wiley, 2003.

[7] H. Akagi, "Trends in Active Power Conditioners", *IEEE Transactions on Power Electronics*, vol.9, no.3, 1994, pp.263-268.

[8] P. Mattavelli, F.B. Pinhabel Maratao, "Repetitive-Based Control for Selective Harmonic Compensations in Active Power Filters", IEEE Trans. On Industr. Electronics, vol.51, no.5, pp.1018-1024, oct. 2004.

[9] J.R.Rodriques, J. W. Dixon, J. R. Espinoza, J.Pontt and P.Lazana, "PWM REGENERATIVE RECTIFIERS. State of the Art", IEEE Trans. On Industr. Electronics, vol.52, no.1, pp.5-22, Jan.2005.

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

[11] D.Alexa, A.Sirbu, D.M.Dobrea: "An Analysis of Three-Phase Rectifiers with Near Sinusoidal Input Currents". *IEEE Trans. On Industrial Electronics,* vol. 51, nr. 4, 2004.

[12] ALEXA, D., SIRBU, A., DOBREA, D., and GORAS T.: "Topologies of three-phase rectifiers with near sinusoidal input currents", IEE Proc. Electr. Power Appl., vol. 151, no. 6, 2004, pp. 673-678.

[13] D. Alexa, A. Sirbu and A.Lazar: "Three-Phase Rectifier with Near Sinusoidal Input Currents and Capacitos Connected on the AC Side", IEEE Trans. Ind. Electron., vol.53, pp. 1612-1620, oct. 2006.

[14] Timothy L. Skvarenina: "The Power Electronics Handbook", CRC Press LLC, 2002.

[15] J.C. Das: "Passive filters-Potentialities and Limitations", IEEE Trans. On Industr. Applications, vol.40, no. 1, 2004, pp. 232-241.