

Investigation of AC/DC Converters with PFC and Output Isolation Diodes

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ABSTRACT

This paper presents computer simulation and experimental results of a research on two parallel connected single phase AC/DC converters with power factor correction and control scheme realized by L4981A controller. The analysis is focused on: power factor and harmonic distortion of the grid current; transient process of settlement of the steady state of the output voltage and its pulsations; output currents sharing at initial start and steady state.

Keywords—power factor correction, parallel operation

I. INTRODUCTION

Theoretical basis of parallel connected DC/DC converters is presented in [1]. There are different methods of load sharing between the different converters depending on their connection-parallel or series [2], [3], [4], [5], [6], [7], [8]. Industrial producers offer specialized controllers for current sharing of parallel connected converters [9], [10], [11], [12]. There are researches on parallel operation of AC/DC converters with PFC which uses different methods [13], [14], [15]. The most popular is the so called “interleaving operation” or “multiphase operation”, in DC/DC converters as well as in AC/DC converters with PFC, for example [4], [5], [15]. Several variations of such AC/DC converters with PFC are described in [16], [17], [18]. The presented methods require resources for additional schemes and sometimes software in the control systems of the converters. The unique function of these additional schemes or software is the current sharing of the output currents.

One popular and effective method for parallel connection of DC/DC converters is by means of “output isolation diodes” [19], [20], [21]. The purpose of this paper is to present the research on the application of the presented method for converters with PFC. It uses two independent converters realized with identical elements. They both are connected to the same grid voltage and their outputs- by means of output isolation diodes. The converters operate independently of one another without any synchronization. The aim of the

research is to determine the sharing of the output voltages and currents during the transient process and steady state. Furthermore to research on the parameters of the grid for both converters – power factor and harmonic distortion of the current as well as the pulsations of the output voltage and to compare them to analogical results in case of one converter.

II. COMPUTER SIMULATION ANALYSIS

Computer simulation analysis is realized by means of PSIM software. Computer simulation model is presented in Fig.1. The values of the main elements are the same as those used for the experimental analysis. Operating frequencies of both converters are 66 kHz and 66.5 kHz. They are set by means of voltage controlled oscillator. Inductances values are 300 μ H, and output capacitor values are 300 μ F. For the simulation analysis of the model of Fig.1 the value of the output voltage for the lower converter is 458V, and for the upper one – 463V. This is implemented by the voltage sources V_{0ref} . The values of these voltage sources are lessened by 33.33. For the computer simulation and experimental analysis the elements defining the transfer functions of the two converters are calculated and set according to the methodology of the producer of the controller L4981A [22]. The effective value of the grid voltage is 230V, and the load resistance value - 137 Ω , which corresponds to an output power of 1.5kW.

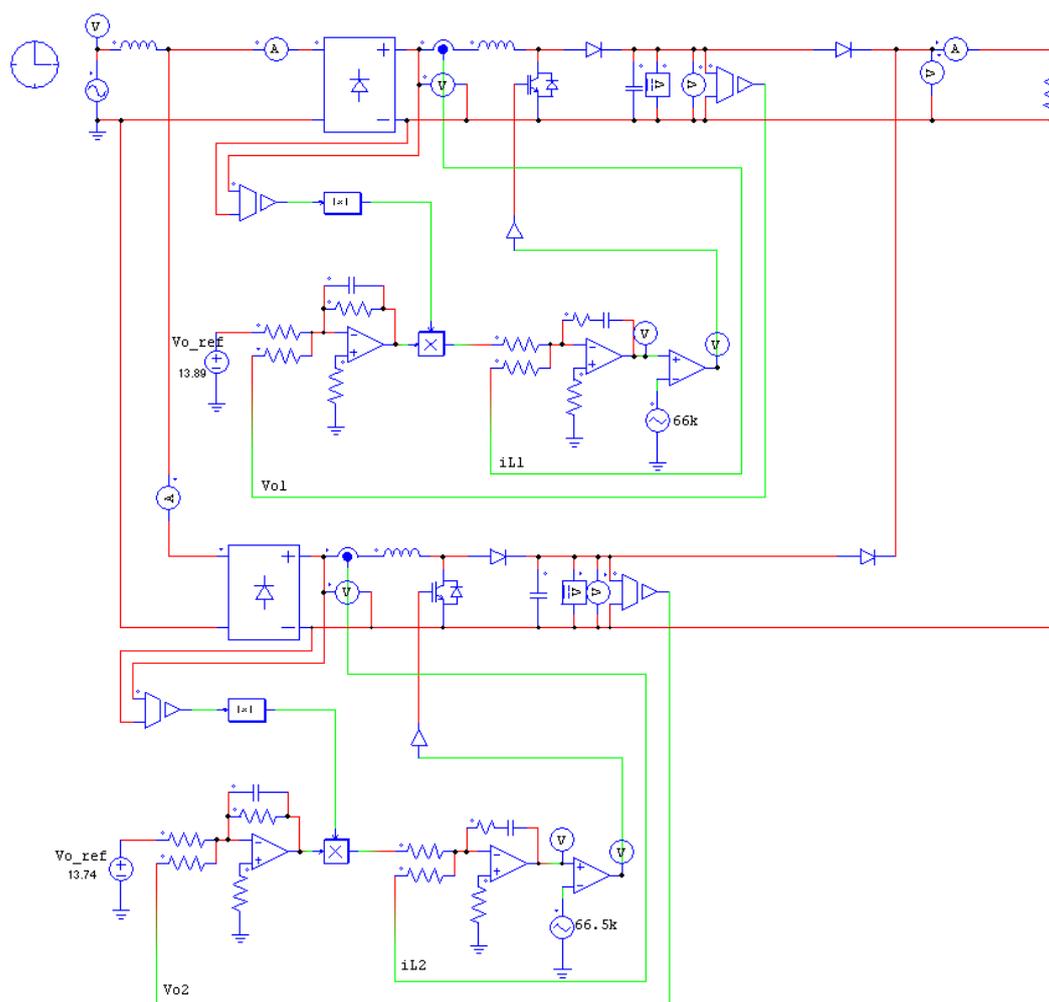


Fig.1. Computer simulation model

In Fig.2 and Fig.3 are presented results of computer simulation for the input currents, and in Fig.4 and Fig.5– for the output voltages of both converters.

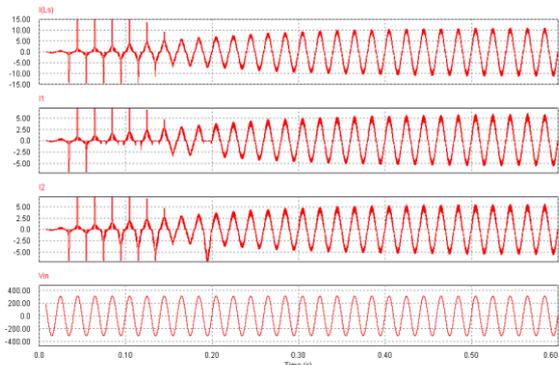


Fig.2. Initial start of the converters. From top to bottom: grid current, input current of the first converter, input current of the second converter, input voltage.

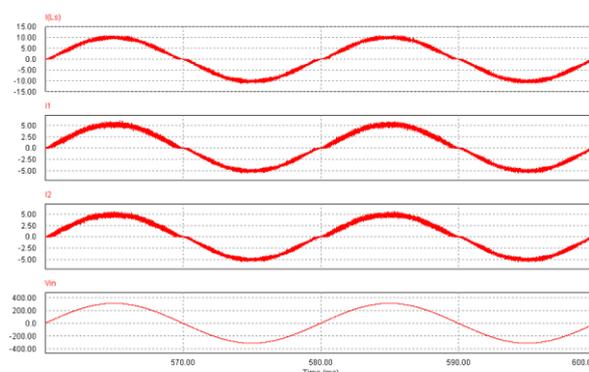


Fig.3. Steay state. From top to bottom: grid current, input current of the first converter, input current of the second converter, input voltage

From the presenetd results in Fig.2 and Fig.3 it is obvious that there is good input current sharing ofboth converters during the initial start as well as during the steady state.

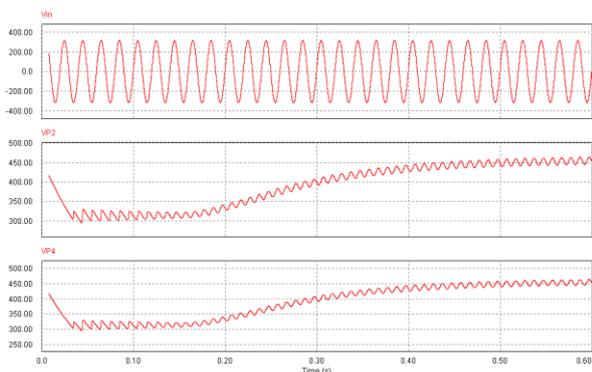


Fig.4. Transient process during the initial start. From top to bottom: input voltage, output voltage of the first converter, output voltage of the second converter.

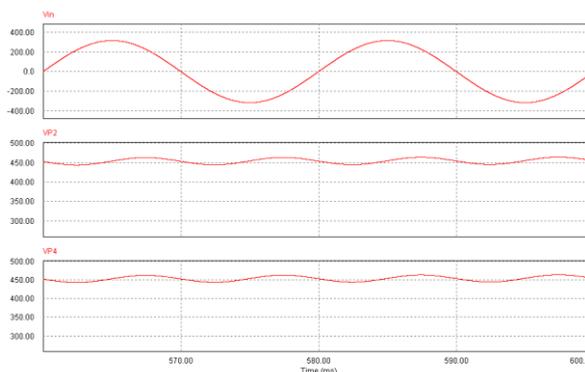


Fig.5. Output steady state. From top to bottom: input voltage, output voltage of the first converter, output voltage of the second converter

In Fig.4 and Fig.5 one can observe that during the initial start both voltages have similar values and steady state output voltages are equalized at the value of 455V.

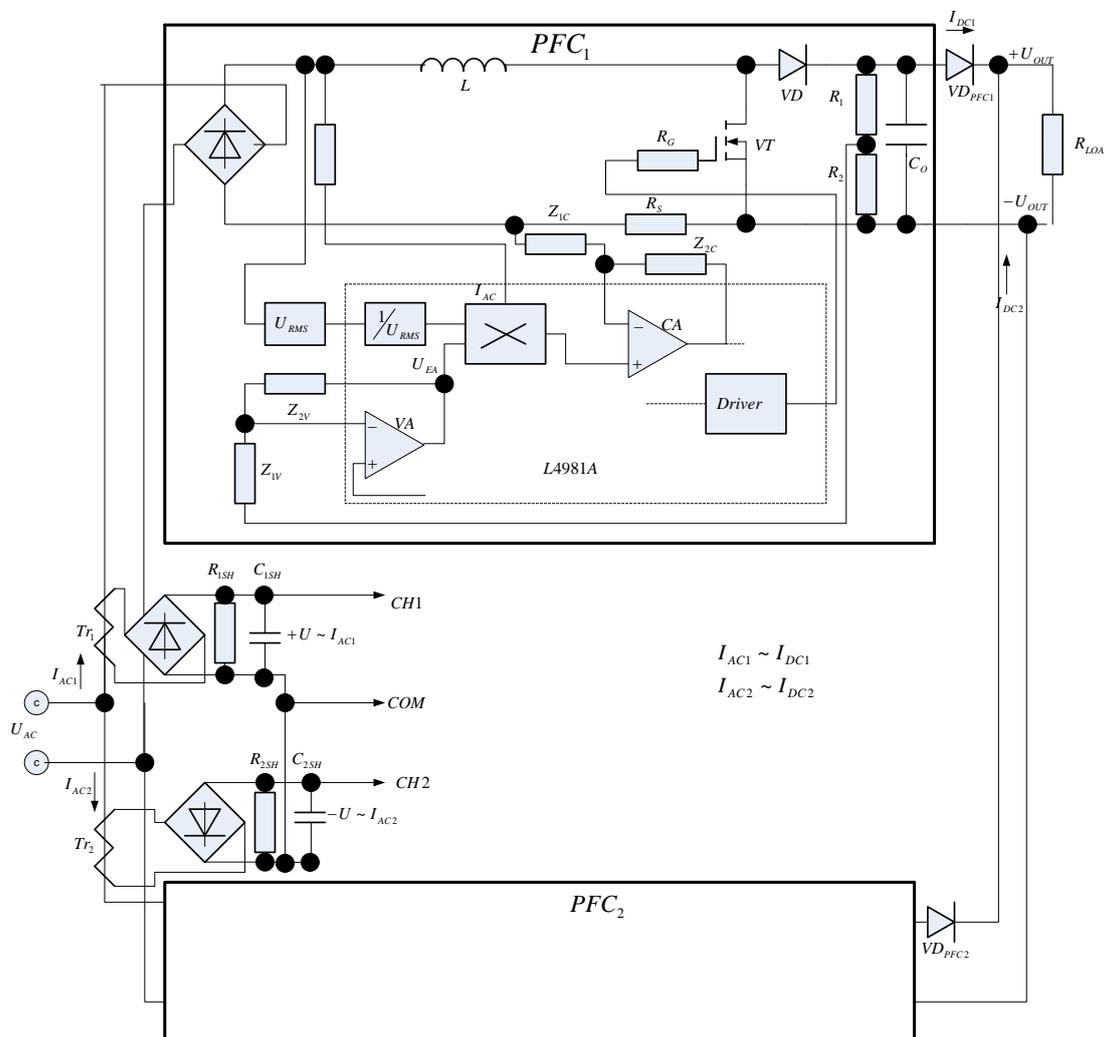


Fig.6. Experimental analysis model

III. EXPERIMENTAL ANALYSIS

The experimental analysis model is presented in Fig.6. For the practical realization each capacitor consists of series connection of two capacitors of 600 μ F, and each of them of six parallel connected capacitors of 100 μ F. It is due to the value of the output voltage- bigger than 450V as well as for the diminution of the equivalent output resistance. The transistors of the boost converters are STN55NM60N, and the diodes – STTH12R06D. Output diodes of both converters are STTH12R06D. For the purpose of the measurements of the input currents, anti harmonic filters are not connected, because they can introduce error in the measurement. Because of the unusual shape of the currents, additional measurement system is realized. It consists of current transformers T_{r1} , T_{r2} and their elements. Current transformers are CR8350 – 2500N of CR Magnetics. They have 10 primary turns and the secondary winding is loaded by a resistor 100 Ω /1%. Capacitor value value is 1000 μ F \pm 1%. So the mean value of the primary current is 2.5A corresponding to an output voltage of 1V to the oscilloscope channels.

As the converters are converters with PFC and if we admit that their efficiency is approximately 1, so the analysis of the experimental results of the output current of each of the converters could be based on the following equation:

$$U_S \cdot I_S \approx U_{OUT} \cdot I_O = \frac{U_{OUT}^2}{R_{LOAD}} \quad (1)$$

U_S , I_S are the effective values of the grid voltage and current. As the input voltage U_S for both modules is the same, as well as the load R_{LOAD} is common, so if equality of the efficient values is settled (or because of the sinusoidal waveform of the current- the mean values) of the input currents, so based on (1) at same output voltage there is equality of output currents I_O . This conclusion is valid in case of efficiency different from 1 but if converters' efficiencies have close values. In Fig.7 is presented the experimental model of the system. In case of independent operation and output current of 1.25A modules output values are 458.8V and 460.3V. Operation frequency difference is below 2%.

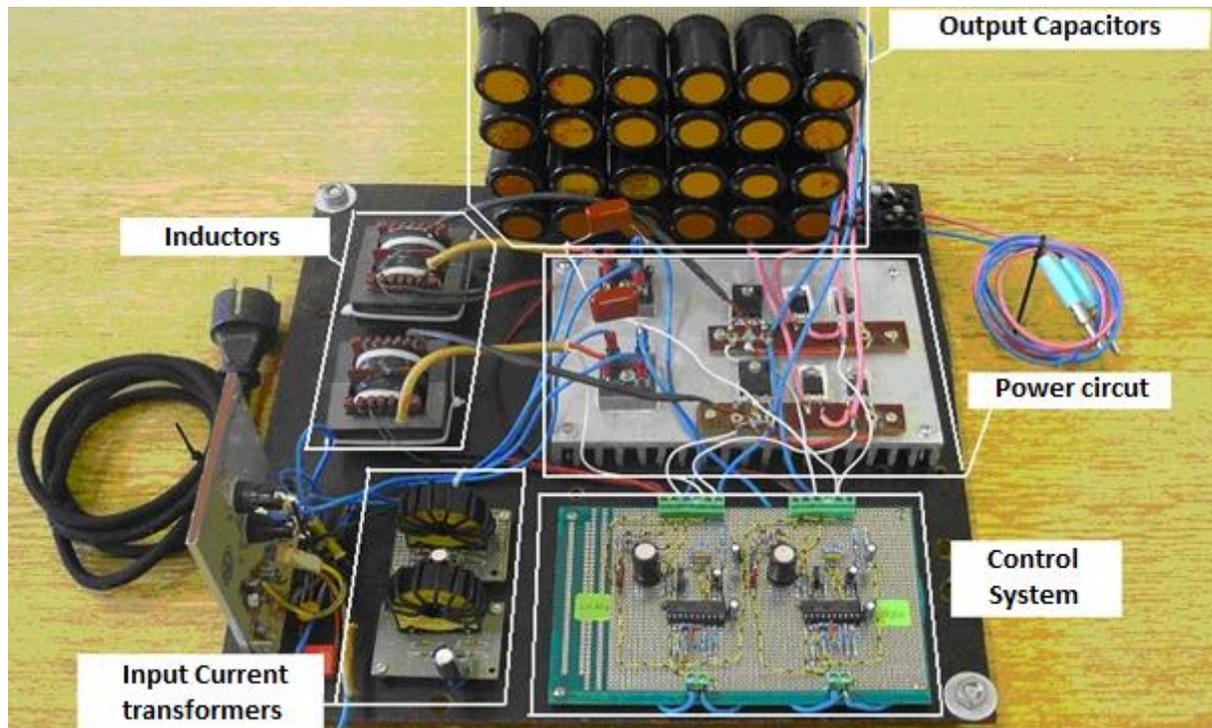
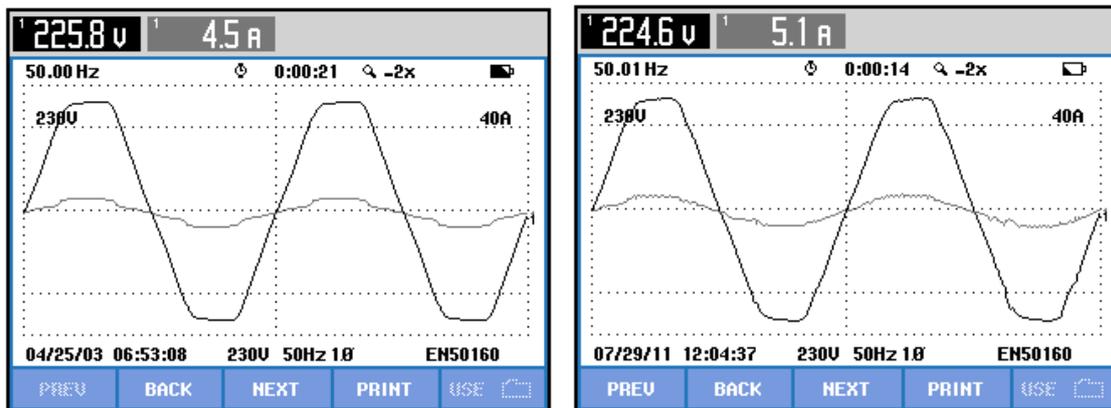
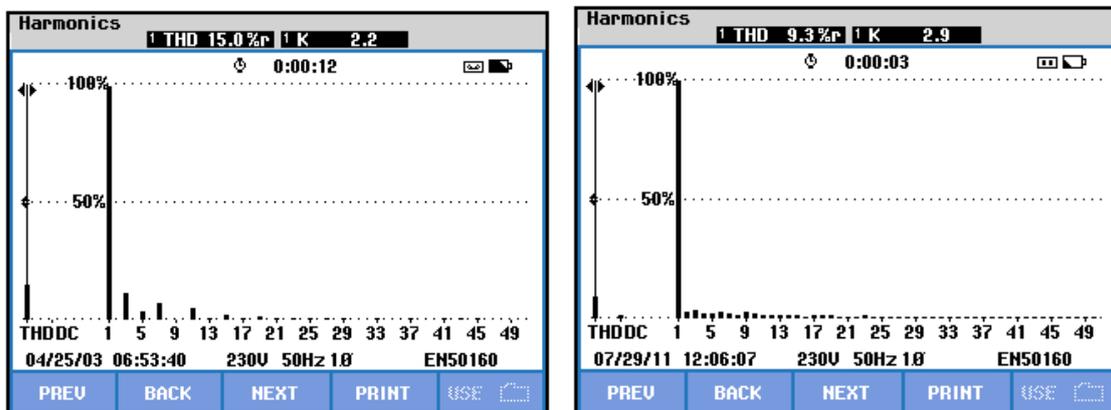


Fig.7. Experimental model

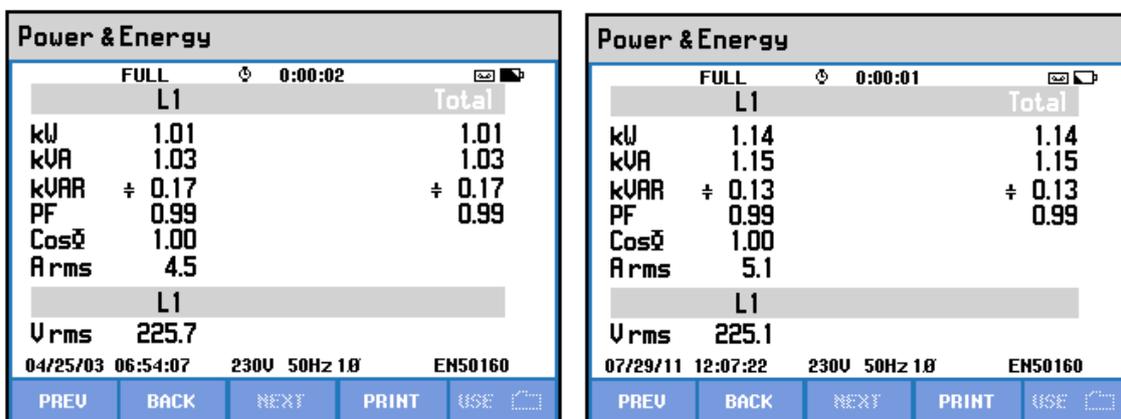
In Fig.8 are presented the grid parameters in case of one or two parallel connected converters operating. The measurements are done by means of Power Quality Analyzer Fluke 434. In case of two converters the current total harmonic distortion is diminishing from 15% to 9.3% at lower values of 3rd, 5th and 7th harmonics.



a) voltage and current of the grid



b) harmonic analysis of the grid current

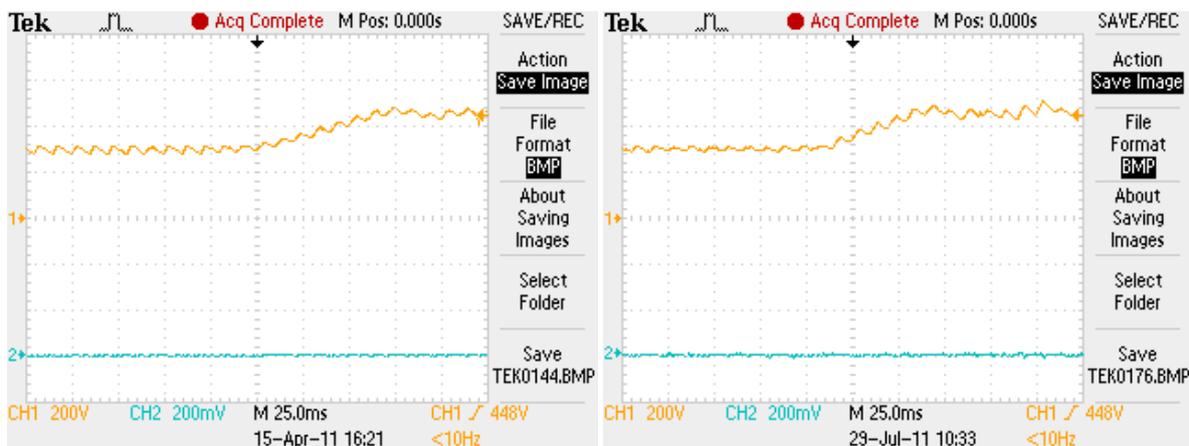


c) power, power factor, $\cos\phi$

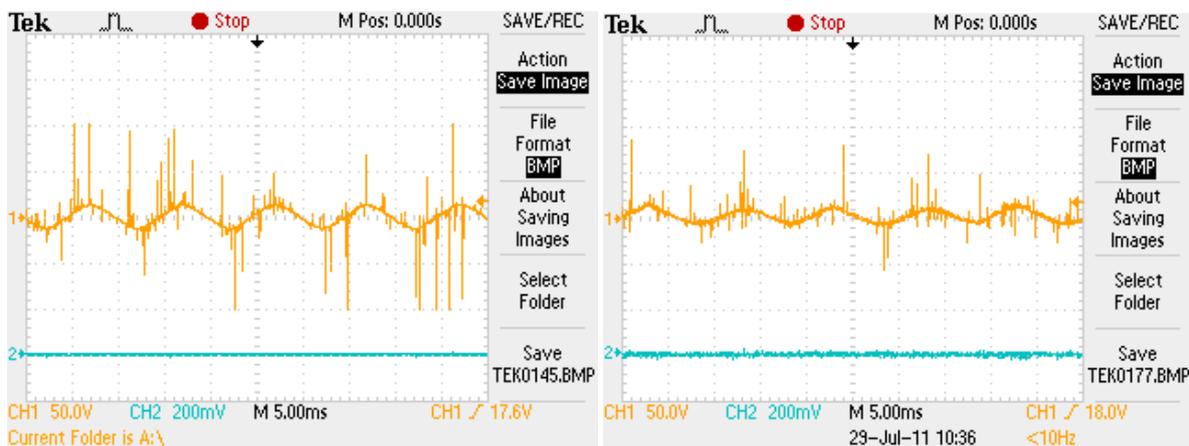
Fig.8. Grid parameters for one converter – left figures and two parallel connected converters- right figures.

In Fig.9 are presented the curves for some characteristic parameters. In case of two parallel connected converters the duration of the transient process during initial start is diminished as well as the pulsations of the output voltage. In case of one converter transient process duration is 50 μ s, and in case of two converters approximately 25 μ s - Fig.9a. In case of one converter operation, pulsation magnitude is approximately 40V, and

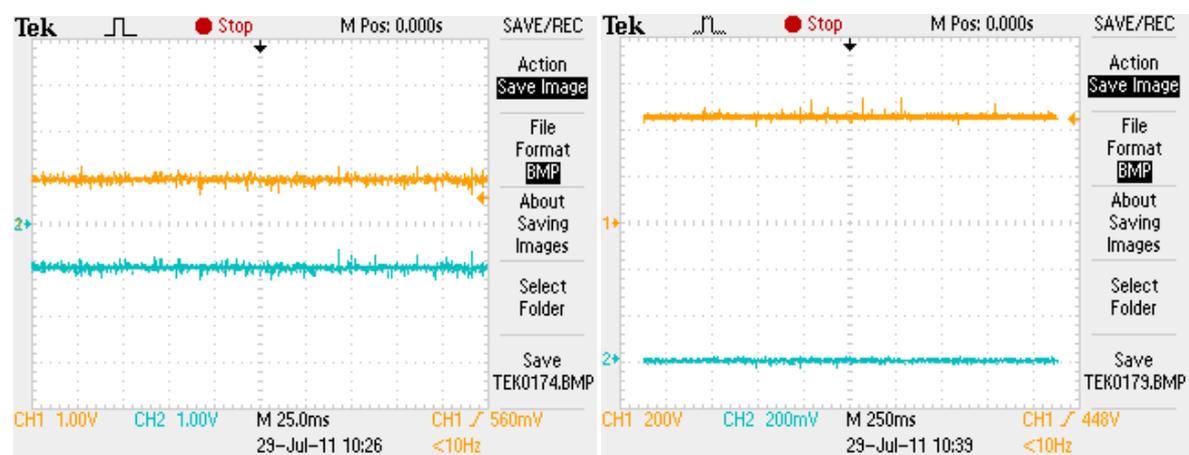
in case of two converters – approximately 20V – Fig.9b. The measured load voltage is 455.5 V. The curves of Fig.9c present the current load of both converters as well as lack of fluctuations of the output voltage with frequency different of its pulsations frequency. The measurement shows current difference of not more than 2%.



a) transient process at initial start for one converter-left figure and two converters-right figure



b) output voltage pulsations for one converter-left figure and two converters-right figure



c) both grid currents values- left figure and output voltage – CH1 of two parallel connected converters – right figure

Fig.9. Transient process curves, output voltage pulsations and input current measurement signals.

IV. Conclusion

The results of this paper present good output currents sharing and improvement of the grid parameters. This is obtained only by the use of output isolation diodes. During their operation there is no synchronization and permanent phase shift, which are typical for the “interleaved converters”, as well as additional measures to equalize the currents by means of control systems. This means that the converters are independent and their parallel connection is easier. This paper completes the method of “output isolation diodes” regarding AC/DC converters with PFC, by obtaining better parameters of the grid.

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