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Multiphase converter with output impedance correction circuit (OICC) based on Peak current mode control (PCMC)

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***Abstract* - An ideal peak current-mode control (PCMC) is only dependent on the dc or average inductor current. It can be done by PID controller with PWM generator. And all this arrangement is called output impedance correction circuit (OICC). The inner current loop turns the induct or into a voltage-controlled current source, effectively removing the inductor from the outer voltage control loop at dc and low frequency. It is used to control the output impedance of converter or inverter circuits. We are using a single universal bridge just to reduce the size. In the proposed model we have connected a filter across the a-b terminal of universal bridge for convert the AC pulses to sine wave.**

Without proposed method we have gotten inverter output only up to 350-400volts. But in proposed model we have increased the output up to 450 volts as the slandered output of inverter.

In the proposed we have used 125volts 50 Hz AC source as a input and we have gotten output 150 volts 50 Hz means same frequency. We are using 400 volts DC or 125 Volts AC supply as input to circuit. First wave form Filtered ac 1000 peak, we know that the standard output of inverter is 400-450 volts.

In the proposed model we have used PCMC for increased the output of inverter, as a standard output of inverter and the pulsated output of inverter (standard 450 volt pulsated AC). It is the final output of proposed model.

Keywords - Peak current-mode control (PCMC), PID controller with PWM generator, output impedance correction circuit (OICC).

I. INTRODUCTION

Power electronics is the “study of processing and controlling the flow of electric energy by implementing solid state switches to meet requirements set by the users. There are many different input and output requirements that a reset by users such as output power, output frequency, input line, etc. Therefore, different types of power electronics devices are used. Depending on the application of the power electronics device used, different solid state switches are used. The Output Impedance Correction Circuit (OICC) concept has been presented in [18]. The solution utilizes an additional energy path, provided by the Output Impedance Correction Circuit (OICC), so that the auxiliary current, injected/extracted trough this path is controlled to have n-1-times higher value than the output capacitor current with appropriate directions. In order to measure the output capacitor current, noninvasive current sensor from [17] is used. This work expands the OICC concept to a Multiphase Buck Converter system while comparing the proposed solution with the system that has n times bigger output capacitor. Furthermore, the OICC is implemented as a Synchronous Buck Converter with PCMC, thus improving the efficiency of the system compared to the solution with Linear Regulator (LR) implementation, presented in [18].

II. THE OUTPUT IMPEDANCE CORRECTION CIRCUIT – IDEAL OPERATION

A Multiphase Buck Converter with Peak Current Mode Control (PCMC) and with the OICC is shown in Fig. 1.1. As explained in [18], the system utilizes the OICC in a manner that the OICC injects/extracts a current in the output node that is

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n-1 times bigger than the output capacitor current with corresponding directions. This behavior of the OICC virtually increases the output capacitance n times during the transients, thus reducing the output impedance by the same factor. The system is composed of the Multiphase Buck converter (black) with a slow regulator (blue) that can be dynamically modified, the OICC (green - power stage, purple - current measurement) behaving like a controlled current source and the system control (red). The control block allows the OICC to inject/extract the current only in the certain states of the transient routine. At the same time, in order to maintain the stability of the system, the control modifies the main converter regulator.

During the steady-state, the OICC is inactive; all energy is transferred trough the Multiphase Buck converter and it is behaving like a voltage source while the system control is observing the output capacitor current in order to initialize the transient routine when a load step occurs. In this manner, by observing the output capacitor current, the system reacts nearly instantaneously to a load perturbation, since the output capacitor current is the fastest variable in the system that sees this perturbation. In Fig. 1.2 the ideal transition routine behavior is presented. The waveforms of the system variables with OICC are presented as a solid line and without the OICC are presented as a dotted line. In the steady state operation, the OICC is turned off and the small load variations are regulated by the low bandwidth regulator. When the load step occurs, the OICC is activated and the output impedance correction starts.

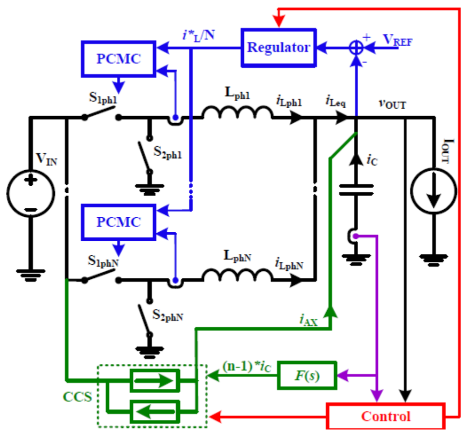

Figure 1.1 - Multiphase Buck Converter with the OICC - Buck converter (black), the current measurement, driving signal generation and the regulator (blue), non-invasive current sensor (purple), the OICC (green) and system control (red).

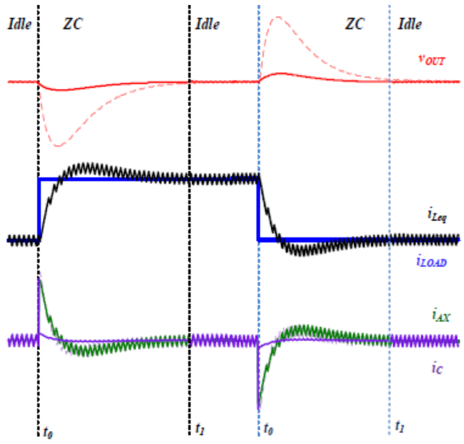

Figure 1.2 - Ideal system waveforms: load step transitions with (solid) and without (dotted) the OICC.

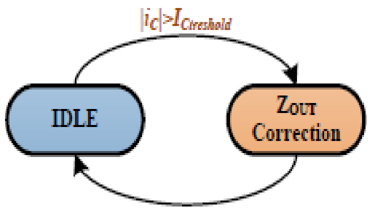

Figure 1.3 - The State machine of the system control. Sign(V_{OUT}(n)-V_{REF}) ≠ signV_{OUT}(n-1)-V_{REF})

The system controller, implemented as a state machine in Fig. 1.3 is triggered by the output capacitor current in the time instant *t0* and the system goes to the ZOUT Correction state (ZC in Fig. 1.2).

In this state, the OICC is providing n-1 times more current than the output capacitor, thus reducing the amount of the charge extracted/injected from/to the output capacitor. As a result, the voltage perturbation is smaller. In order to end the ZOUT Correction state, the system controller is observing the output voltage error signal. When the error signal sign is changed in *t1*, the output voltage is equal or close to the reference voltage and that event triggers the system controller which returns the system back to the idle state.

During the Idle state, the output capacitance is C, but during the ZOUT Correction state, the equivalent capacitance in ideal case is n·$_{C.}$ This affects the PCMC Multiphase Buck converter averaged model and, therefore, the stability requirements related to the regulator modification addressed in [18] need to be satisfied.

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III. SYNCHRONOUS PCMC WITH BUCK OICC

The OICC implementation is presented in Fig. 3.1. The OICC subsystem is composed of non-invasive current sensor (purple) designed by applying the impedance matching procedure presented in [17], the auxiliary current reference generator, the current ripple compensation block and High-switching frequency Synchronous Buck converter with PCMC that operates as a controlled current source (CCS), shown in Fig. 1.1. When the OICC is active, the CCS is injecting an auxiliary current i_{AX} at the output node composed of the mean value given by the auxiliary current reference generator v_{AXref} and the high frequency component generated by the Buck converter. Since the Buck converter is PCMC controlled, an offset between the current reference v_{Iref} and the mean value of the auxiliary current i_{AX} exists due to the current ripple, the compensation ramp and due to the turn on/off delays of the PCMC modulator. Therefore, the current ripple compensation block is employed to compensate the difference by adding v_{COMP} to the auxiliary current reference voltage v_{AXref}, thus ensuring that the mean value of the auxiliary current i_{AX} equals to the auxiliary current reference voltage v_{AXref}.

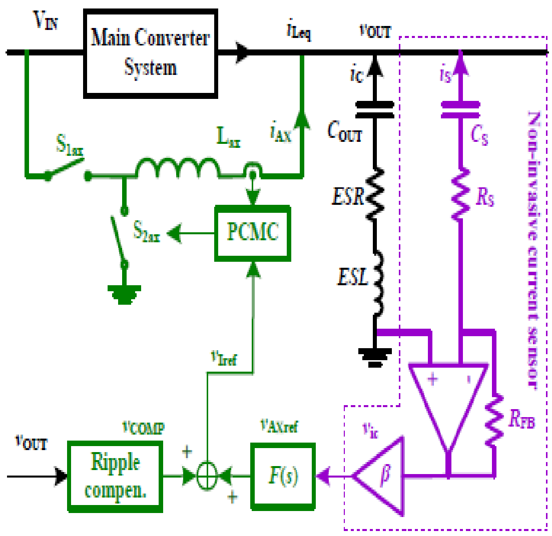

Fig. 3.1 - Implementation of the OICC – Synchronous Buck converter with PCMC, auxiliary reference generator and current ripple compensation (green), non-invasive current sensor (purple) and the main power stage (black).

Fig. 3.2 shows PCMC waveforms and it can be seen that, due to the type of the modulation, the mean value of the auxiliary current i_{AX} is not equal to the current reference v_{Iref}. Depending on the slope of the compensation ramp m_C, turn-on and turn-off delay ($t_{HI\uparrow}$ and $t_{HI\downarrow}$) as well on the comparator delay t_{COMP}, the difference between the current reference v_{Iref} and the mean value of the auxiliary current i_{AX}, which needs to be compensated by the compensation block v_{COMP}.

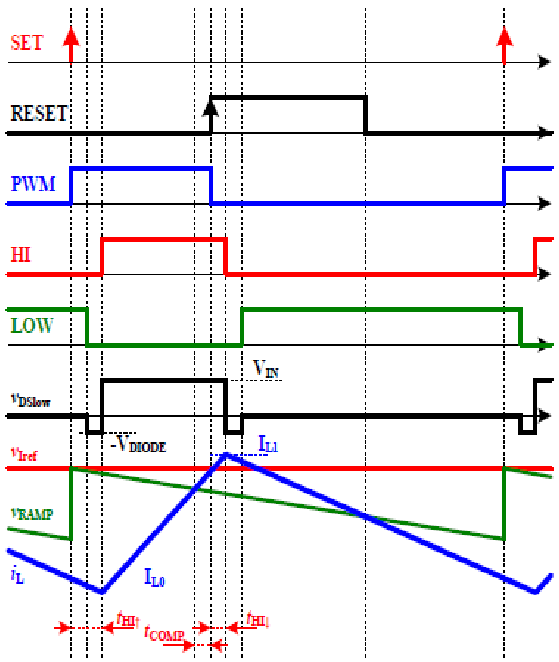

Fig. 3.2 - PCMC waveforms with delays.

IV. SIMULATION MODEL & RESULT ANALYSIS

The basic circuit model of inverter is shown in below Fig. 4.1.

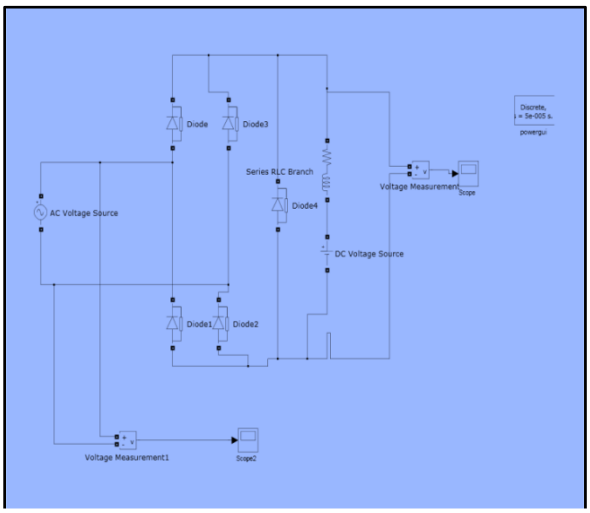

Fig. 4.1 - Basic circuit model of inverter

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It is consist of four diodes but in proposed model, we are using a single universal bridge just to reduce the size. The output of inverter circuit is DC-AC in the form of AC pulses. In the proposed model we have connected a filter across the a-b terminal of universal bridge for convert the AC pulses to sine wave.

The proposed model has been developed by MATLAB simulink as shown in below Fig. 4.2.

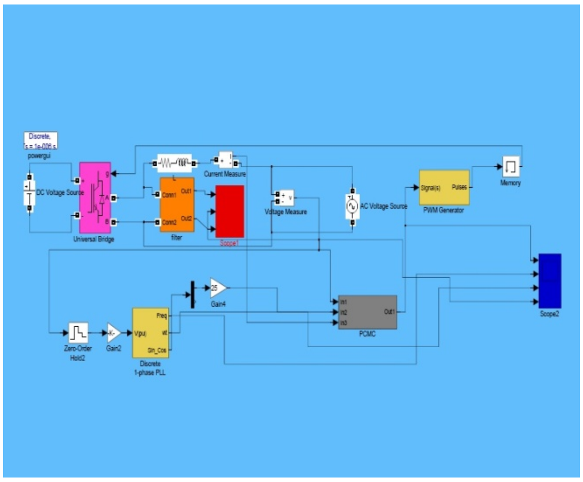

Fig. 4.2 - Proposed model has been developed by MATLAB simulink

Without proposed method we have gotten inverter output only up to 350-400volts. But in proposed model we have increased the output up to 450 volts as the slandered output of inverter.

1-phase PLL is phase lock loop. It is used for pass the voltage to the controller block but lock the frequency for making output frequency is equal to input frequency. In the proposed we have used 125volts 50 Hz AC source as a input and we have gotten output 150 volts 50 Hz means same frequency.

An ideal PCMC (peak current-mode control) is only dependent on the dc or average inductor current. It can be done by PID controller with PWM generator or zero order hold. And all this arrangement is called OICC (output impedance correction circuit)

SCOPE 1:

We have gotten three wave forms from scope 1 is shown in below Fig. 4.3. We are using 400 volts DC or 125 Volts AC supply as input to circuit. First wave form filtered ac 1000 peak, we know that the standard output of inverter is 400-450 volts. In the proposed model we have used PCMC for increased the output of inverter, as a standard output of inverter. Second wave form is 125 AC supply. And third wave form are showing the pulsated output of inverter (standard 450 volt pulsated AC). It is the final output of proposed model.

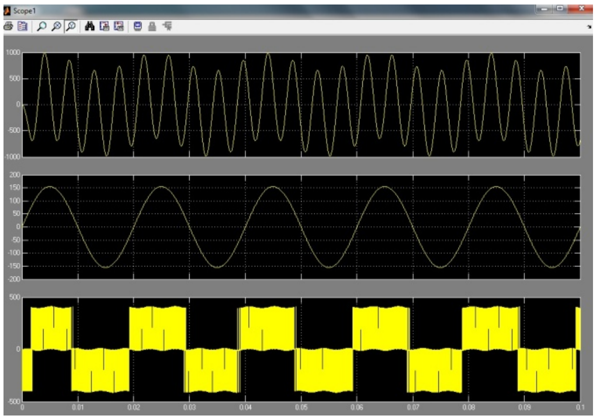

Fig. 4.3 - Scope 1

SCOPE 2:

We have gotten four waveforms from scope 2. The first wave form is showing the output of digital control, its output in between +0.5 to -0.5. It is used for giving the signal to the gate of universal bridge through PWM.Second wave form is showing the frequency 50 Hz. Third wave form is showing the Ramp, varying between 0 and 2*pi, synchronized on the zero-crossing (rising) of the fundamental of input signal.Forth wave form is showing the 125 volts AC supply (just to compare).

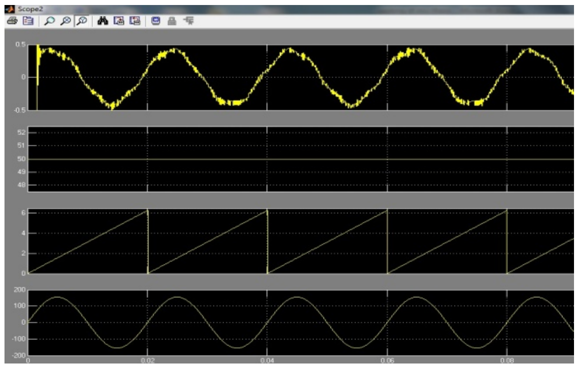

Fig. 4.4 - Scope 2

V. CONCLUSION

This actually investigates the effect of unity-gain output current- feed forward in a peak-current-mode-controlled (PCMC) buck converter. A consistent theoretical basis is provided showing that the unity-gain feed forward can improve significantly the load invariance and transient

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performance of a PCMC buck converter. The non-idealities associated to the scheme would, however, deteriorate the obtainable level of invariance. The non-idealities can be maintained at acceptable level, and therefore, the scheme would provide a viable method to reduce significantly the load interactions as well as improve the load-transient response. The theoretical predictions are supported with comprehensive experimental evidence both at frequency and time domain as well as comparisons between different buck converters.

The use of output-current feed-forward has been demonstrated to improve the output-voltage transient performance for the load-current changes in a hysteretic current-mode-controlled (HCMC) buck converter in. According to the applied theory, the zero output impedance would be achieved by using unity-feed-forward gain. The peak-current-mode-controlled (PCMC) buck converter is treated. The effect of output-current feed-forward on the output impedance of the converter is comprehensively analyzed. Close to unity-feed-forward gain is stated to give the minimum output impedance. The general conditions for achieving zero output impedance have been derived. It was stated that the zero output impedance can be implemented in any converter regardless of topology but the validations were only carried out by using a buck converter.

A voltage-mode-controlled (VMC) buck converter has been treated in but the theoretical basis for the design approach is not explicitly defined and therefore, the validation of the method is difficult. The experimental load transients shown in imply that the zero output impedance may not be achievable in a boost converter by applying output-current feed-forward, i.e., a better transient behavior may be achieved by optimizing the voltage-loop-controller design. The dynamical effect of unity-load-current feed-forward in a PCMC buck converter was investigated. A sound theoretical formulation was defined and applied to obtain an analytical description of the internal dynamics of such a converter. The dynamical characterization proved the previous findings but introduced also new earlier unobserved features. It was stated that a PCMC–OCF buck converter may possess both high invariance to supply and load side interactions, if an optimal slope compensation and a match in the inductor- and load-current sensing resistors exist.

The match error in the sensing resistors would increase the open-loop output impedance and make the converter more sensitive to load interactions. It may be possible to maintain the match error sufficiently small, and therefore, the unity output-current-feed-forward would provide a method to significantly reduce the load and supply side interactions.

VI. REFERENCES

[1] D. Goder and W. R. Pelletier, “V2 architecture provides ultra-fast transient response in switch mode power supplies”, in Proc. High Frequency Power Conversion Conf., 1996, pp. 19-23.
[2] J. Li and F. C. Lee, “Modeling of the V2 type current-mode control,” in IEEE Trans. Circuits and Systems., vol. 57, no. 9, pp. 2552–2563, Sept. 2010.
[3] A. Soto, P. Alou, J.A. Cobos, “Nonlinear Digital Control Breaks Bandwidth Limitations,” in Proc. IEEE App. Power Electron. Conf. Expo. (APEC), 2006, pp. 724–730.
[4] M. del Viejo, P. Alou, J.A. Oliver, O. Garcia, J.A. Cobos, “Fast control technique based on peak current mode control of the output capacitor current,” in Proc. IEEE Energy Convers. Congr. Expo. (ECCE), 2010, pp. 3396–3402.
[5] M. Del Viejo, P. Alou, J.A. Oliver, O. Garcia, J.A. Cobos, “V2IC Control: a Novel Control Technique with Very Fast Response under Load and Voltage Steps,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 2011, pp. 231–237.
[6] P. S. Shenoy, P. T. Krein, S. Kapat, “Beyond Time-Optimality: Energy-Based Control of Augmented Buck Converters for Near Ideal Load Transient Response,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 2011, pp. 916–922.
[7] L. Amoroso, M. Donati, X. Zhou and F. C. Lee, “Single shot transient suppressor (SSTS) for high current high slew rate microprocessor,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 1999, pp. 284–288.
[8] E. Meyer, Zhiliang Zhang, Yan-Fei Liu, “Controlled Auxiliary Circuit to Improve the Unloading Transient Response of Buck Converters,” IEEE Trans. Power Electron., vol. 25, no. 4, pp. 806–819, April 2010.
[9] E. Meyer, Dong Wang, Liang Jia, Yan-Fei Liu, “Digital Charge Balance Controller with an Auxiliary Circuit for Superior Unloading Transient Performance of Buck Converters,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 2010, pp. 124–131.
[10] Liang Jia, Zhiyuan Hu, Yan-Fei Liu, P. C. Sen, “A Practical Control Strategy to Improve Unloading Transient Response Performance for Buck,” in Proc. IEEE Energy Convers. Congr. Expo. (ECCE), 2011, pp. 397–404.

[11] Yue Wen, O. Trescases, “Non-Linear Control of Current-Mode Buck Converter with an Optimally Scaled Auxiliary Phase,” in Proc. IEEE Int. Conf. Ind. Techn. (ICIT), 2010, pp. 783–788.
[12] Yue Wen, O. Trescases, “DC-DC Converter with Digital Adaptive Slope Control in Auxiliary Phase to Achieve Optimal Transient Response,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 2011, pp. 331–337.
[13] A. M. Wu, S. R. Sanders, “An Active Clamp Circuit for Voltage Regulation Module (VRM) Applications,” IEEE Trans. Power Electron. vol. 16, no. 5, pp. 623–634, Sep. 2001.
[14] A. Barrado, A. Lázaro, R. Vázquez, V. Salas, E. Olías, “The Fast Response Double Buck DC–DC Converter (FRDB): Operation and Output Filter Influence,” IEEE Trans. Power Electron., vol. 20 no. 6, pp. 1261–1270, Nov. 2005.
[15] Xiancheng Wang, Qingshui Li, I. Batarseh, “Transient Response Improvement in Isolated DC-DC Converter with Current Injection Circuit,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 2005, pp. 706–710.
[16] O. Abdel-Rahman, I. Batarseh, “Transient Response Improvement in DC-DC Converters Using Output Capacitor Current for Faster Transient Detection,” in Proc. IEEE Power Electron. Spec. Conf. (PESC), 2007, pp. 157–160.
[17] S. C. Huerta, P. Alou, J.A. Oliver, O. Garcia, J.A. Cobos, A. Abou-Alfotouh, “Design methodology of a noninvasive sensor to measure the current of the output capacitor for a very fast non-linear control,” in Proc. IEEE App. Power Electron. Conf. Expo.(APEC), 2009, pp. 806–811.
[18] V. Šviković; J. A. Oliver; P. Alou; O. García; J. A. Cobos, “Synchronous Buck Converter with Output Impedance Correction Circuit,” in Proc. IEEE App. Power Electron. Conf. Expo. (APEC), 2012, pp. 727–734
[19] V. Šviković; P. Alou; J. A. Oliver; O. García; J.A. Cobos, Centro de Electrónica Industrial Universidad Politécnica de Madrid Madrid, Spain “ Multiphase Current Controlled Buck Converter with Energy Recycling Output Impedance Correction Circuit (OICC)” in Proc. IEEE, 978-1-4673-4355-2013, pp. 263-269.

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