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Performance Evaluation Fast Transient Response DC-DC Converter using Soft Computing Analysis with PI Controller

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ABSTRACT

In this paper, a fast transient response double buck converter using soft computing method is introduced. The regional anatomy of the FRDB is composed of two buck converters connected in parallel, each one of them with different characteristics. FTRDB provides a faster transient response to match the challenges of the power supply requirements for fast dynamic input and load changes. It also offers better stability and works out the compensation problem of the error amplifier in duty ratio control. A PI controller used for duty ration control of proposed fast transient response DC-DC converter. Genetic algorithm (GA) and Particle Swarm optimization (PSO) algorithms are applied to determine the gain values of the PI controller to determine the perfect duty ratio control. Lastly, the steady-state and dynamic performance of the proposed control method are analyzed and verified by conventional buck converter using MATLAB/Simulink software platform.

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INTRODUCTION

Nowadays, DC-DC converters play a substantial role in the industry, the aerospace industry, portable systems, distributed generation, electrical devices, electrical cars, power factor correction and voltage regulation (Kim et.al, 2010, Liou, et.al, 2008, Khaligh, et.al, 2008, Cha, et.al, 2008, Villava, et.al, 2008). Therefore, high-quality power supplying converters that can accomplish low-cost and high-efficiency performance are in demand (Huang, et.al, 2009). Buck converters, as unitary of the widely used converters, have been investigated with different social systems and control methods (Huang, et.al, 2009, Chen et.al, 2007, Siu et.al, 2006, Zheng et.al, 2012, Wu, X. H. et.al, 2010, Castilla, et.al, 2007, Nabeshima et.al, 2005, Khaligh et.al, 2008, Cha et.al, 2008, Villava, and Ruppert 2008, Mohsen et.al, 2010, Huerta et.al, 2011, Huerta et.al, 2012, Kapat and Krein 2012). These types of devices need power supplies with the low output voltage, high output current, and the main challenge of fast transient response (Goodfellow and Weis 1997, Intel, AP-907 Pentium® III, 2005, Zhou et.al, 1998, Wei et.al, 2001). Different techniques used in order to improve the transient response of these types of power supplies: The fast response double buck converter (FRDB converter) was presented like a dc–dc switching converter, which can be considered an alternative to the voltage regulator module (VRM) converters in some applications (Barrado et.al, 2003). PI controller is applied in this work for determining the output potential of fast transient response DC-DC converter under supply and load disturbances. Tests for load regulation and line regulation are held away to evaluate the controllers' performances. The results are presented and evaluated.

Fast Transient Response Dc-Dc Converter:

The regional anatomy of this converter is composed of two switching converters connected in parallel. It is critical to take into account the fact that although both converters are connected in parallel, they sustain to be designed with different roles, and therefore, the surgical procedure does not match a typical parallel operation. In the fast transient response DC-DC converter, the main switching converter must be designed to work in the steady-state operation, and therefore with good stability and a low output voltage ripple, but consequently with slow reaction. On the reverse, the auxiliary switching converter must be designed to run in transient operation. The primary purpose of the auxiliary converter is to provide the required high current slew

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rate and quick transient response. Nevertheless, low output voltage ripple is not a prerequisite for the auxiliary converter. Fig. 1 shows the block diagram of the fast transient response DC-DC converter.

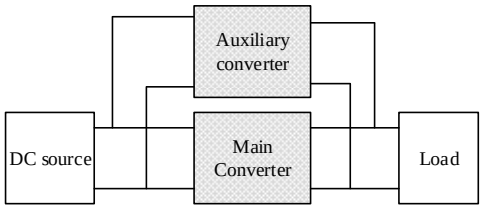

Fig. 1: Structure of fast transient response DC-DC converter.

The circuit diagram of the fast transient response DC-DC converter shown in Fig.2. In this design, two buck topologies have been used to design the auxiliary and main converter. Both of them feed the output in parallel. Furthermore, a control block can be detected. Essentially, the control block is composed of direct control, non-linear control, and ultimately, a multiplexer (MUX). In short, and from a topological point of view, the principle operation is based on preventing the main switching converter operating all the time, connecting the auxiliary switching converter only at the edges of the load current steps. In this manner, the auxiliary converter completes the main converter performances to satisfy the demands.

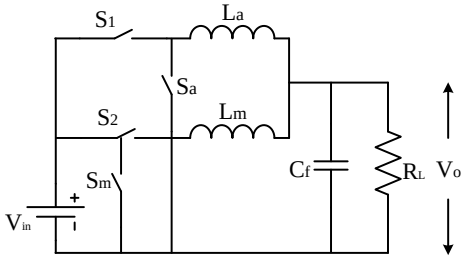

Fig. 2: Circuit diagram of fast transient response DC-DC converter.

Control Strategy of fast transient response DC-DC converter:

PI controllers used for several decades in industries for process control applications. The reason for their wide popularity lies in the simplicity of design and good performance including low percentage overshoot and small settling time for slow process plants. The most appreciated feature of the PI controllers is their relative easiness of use because the three involved parameters have a clear physical meaning. This controller makes their tuning possible for the operators also by trial and error and in any case a large number of tuning rules have been developed.

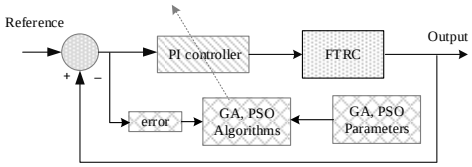

Fig. 3: Structure of PI controller fed fast transient response DC-DC converter.

Although all the existing techniques for the PI controller parameter tuning perform well, a continuous and an intensive research work is still underway towards system control quality enhancement and performance improvements. A PI controller is essentially a generic closed loop feedback mechanism. In working principle is that it monitors the error between a measured process variable and a desired set point; from this error, a corrective signal is computed and is eventually feedback to the input side to adjust the process accordingly. The differential equation for the PI controller is as follows,

$$u(t) = K_p e(t) + T_i \int_o^t e_p(t)dt \quad (1)$$

Thus, the PID controller algorithm is described by a weighted sum of the three times functions were the three distinct weights are: K_P (Proportional gain) determines the influence of the present error value on

the control mechanism, I (integral gain) decides the reaction based on the area under the error time curve up to the present point accounts for the extent of the reaction to the rate of change of the error with time (Astrom and Hagglund, 1995). The structure of PI controller fed FRDB converter is shown in Fig.3.

Simulation Results:

In this work, a conventional buck converter performance compared with the proposed fast transient response DC-DC converter. Both converter control strategies are checked by the controlling duty ratio using soft computing algorithms such as Genetic Algorithm and Particle Swarm Optimization algorithm. The algorithms are utilized to tune the gain values of the PI controller. Established along the controller response the duty ratio of the proposed converter has been moderated. The Simulink diagram of the conventional buck converter and proposed fast transient response DC-DC converter shown in Fig.4 and 6 respectively. The simulated graphical analysis of the both converter shown Fig.8 to 13. Fig.5 shows the open loop analysis of conventional buck converter, from this figure, the response of all curves under various load conditions are not stable, whereas the open loop performance of the proposed fast transient response DC-DC converter is stable shown in Fig.7.

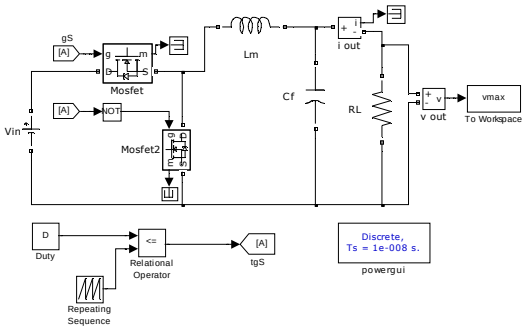

Fig. 4: Simulink diagram of conventional Buck converter.

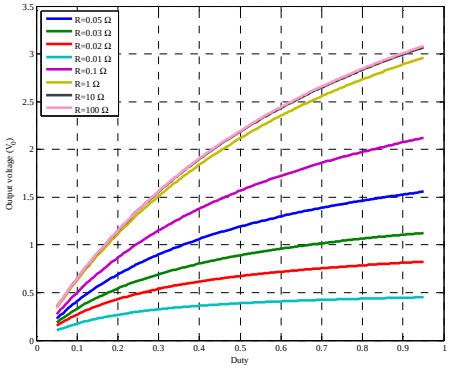

Fig. 5: Open loop analysis of conventional Buck converter.

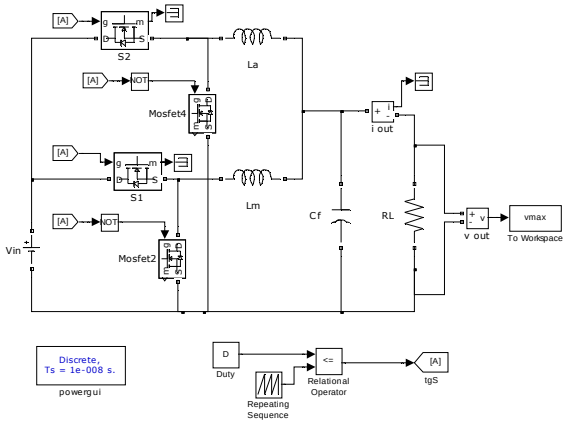

Fig. 6: Simulink diagram of proposed fast transient response DC-DC converter.

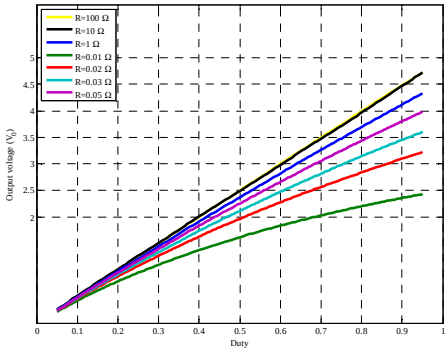

Fig. 7: Open loop analysis of proposed fast transient response DC-DC converter.

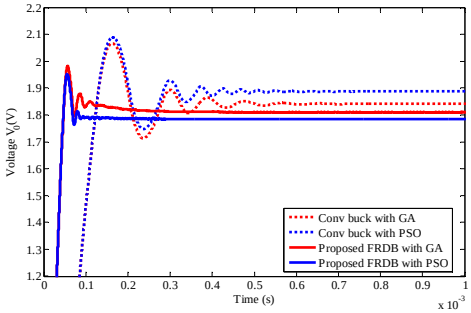

Fig. 8: Simulated start-up of the output voltage waveform of fast transient response DC-DC converter.

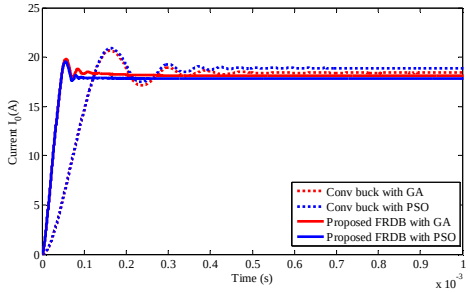

Fig. 9: Simulated start-up of the output current waveform of fast transient response DC-DC converter.

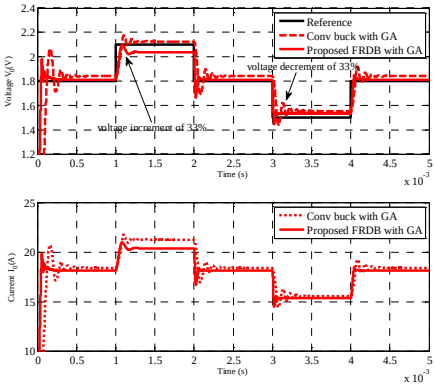

Fig. 10: Simulated output voltage and current waveform of fast transient response DC-DC converter with sudden line disturbances using GA PI controller.

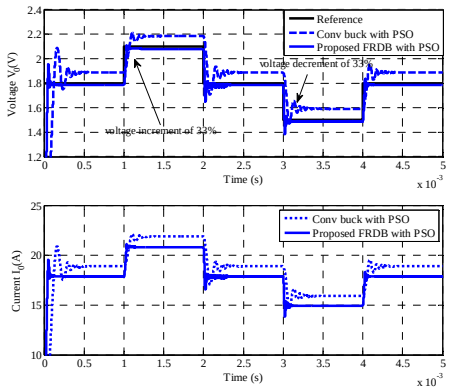

Fig. 11: Simulated output voltage and current waveform of fast transient response DC-DC converter with sudden line disturbances using PSO PI controller.

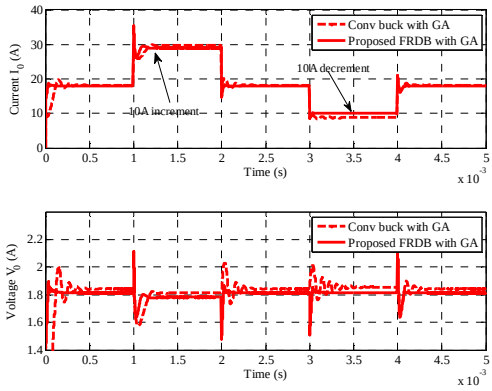

Fig. 12: Simulated output voltage and current waveform of fast transient response DC-DC converter with sudden load disturbances using GA PI controller (10 A increment and decrement).

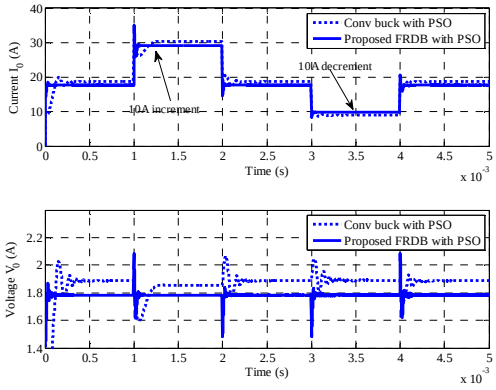

Fig. 13: Simulated output voltage and current waveform of fast transient response DC-DC converter with sudden load disturbances using PSO PI controller (10 A increment and decrement).

Table I: Performance analysis of FTR converter with conventional buck converter.

Converters	Start up				Sudden line disturbance				Sudden load disturbances			
	GA		PSO		GA		PSO		GA		PSO	
	T_s (sec) x 10^{-4}	$\%M_p$	T_s (sec) x 10^{-4}	$\%M_p$	T_s (sec) x 10^{-4}	$\%M_p$	T_s (sec) x 10^{-4}	$\%M_p$	T_s (sec) x 10^{-4}	$\%M_p$	T_s (sec) x 10^{-4}	$\%M_p$
Conventional buck	7.224	12.79	5.922	9.047	5.074	10.85	5.033	9.434	0.379	6.870	3.443	5.98
FTR Converter	3.116	8.58	1.474	8.45	2.557	8.131	1.791	7.88	1.207	18.21	1.127	11.48

Figs.8 and 9 established the closed loop response of start-up of the output voltage and current wave shape of conventional buck and proposed fast transient response DC-DC converter with PI controller. Figs.10 and 11 demonstrated the simulated output voltage and current wave shape of conventional buck and proposed fast transient response DC-DC converter with sudden line disturbances due to supply increment and decrement. The Figs.10 and 11 shows the servo response with

33% growth and 33% decrement from the set voltage at time t=1 msec and 3 msec respectively. Figs.12 and 13 demonstrated the simulated output voltage and current wave shape of conventional buck and fast transient response DC-DC converter with sudden load disturbances. The Figure depicts the response with increment and decrement of 10A load. Table.1 shows the simulated performance analysis of fast transient response DC-DC converter using soft computing methods with a comparison of the conventional buck converter. From the table, it is discovered that the fast transient response DC-DC converter with PSO PI controller produced good performance and fast settling time compared to the conventional buck converter.

Conclusion:

Fast transient response DC-DC converter is composed of two buck converters connected in parallel and controlled by PI control. This solution significantly reduces the recovery time and the output voltage variation in comparison with a conventional buck converter, The Simulation results show that the proposed PI controller regulates satisfactorily the output voltage of fast transient response DC-DC converter irrespective of line and load disturbances. It also overcomes the effects of the conventional buck converter. fast transient response DC-DC converter presents an excellent stability, due to PI control, keeping a low output voltage ripple and fast transient response. As well, it allows for reducing the steady-state switching frequency affecting the EMI and the switching losses.

REFERENCES

Kim, I.D. J.Y. Kim, E.C. Nho, H.G. Kim, 2010. Analysis and design of a soft-switched pwm sepic dc-dc converter. Journal of Power Electronics. 10(5): 461-467.

Liou, W.R., M.L. Yeh, Y.L. Kuo, 2008. A high efficiency dual-mode buck converter integrated circuit for portable applications. IEEE Trans. Power Electron, 23(2): 667-677.

Khaligh, A. A.M. Rahimi and A. Emadi, 2008. Modified pulse-adjustment technique to control dc/dc converters driving variable constant-power loads. IEEE Trans. Ind. Electron, 55(3): 1133-1146.

Cha, H.Y., R.J. Ding, Q.S. Tang, F.Z. Peng, 2008. Design and development of high power dc-dc converter for metro vehicle system. IEEE Trans. Ind. Appl, 44(6): 1795-1804.

Villava, M.G. and E.F. Ruppert, 2008. Input-controlled buck converter for photovoltaic applications: modeling and design. in Proc. PEMD, 505-509.

Huang, H.H., C.L. Chen, K.H. Chen, 2009. Adaptive window control (AWC) technique for hysteresis DC-DC buck converters with improved light and heavy load performance. IEEE Trans. Power Electron, 24(6): 1607-1617.

Chen, K.H. H.W. Huang, S.Y. Kuo, 2007. Fast transient DC–DC converter with on-chip compensated error amplifier. IEEE Trans. Circuits Syst. II, 54(12): 1150-1154.

Siu, M., P.K.T. Mok, K.N. Leung, Y.H. Lam and W.H. Ki, 2006. A voltage-mode PWM buck regulator with end-point prediction. IEEE Trans.on Circuits Syst. II, 53(4): 294-298.

Zheng, Y.Q. H. Chen and K.N. Leung, 2012. A fast-response pseudo-PWM buck converter with PLL-based hysteresis control. IEEE Trans. Very Large Scale Integr. (VLSI) Syst., 20(7): 1167-1174.

Wu, X.H. and X.B. Wu, 2010. Adaptive hysteresis window control (AHWC) technique for hysteresis DC-DC buck converter with constant switching frequency. Power and Energy Engineering Conference, 1-4.

Castilla, M., L. Garcia de Vicuna, J.M. Guerrero, J. Miret, N. Berbel, 2007. Simple low-cost hysteresis controller for single-phase synchronous buck converters. IEEE Trans. Power Electron, 22(4): 1232-1241.

Nabeshima, T., T. Sato, K. Nishijima, S. Yoshida, 2005. A novel control method of boost and buck-boost converters with a hysteresis PWM controller. In Proc.EPE, 1-6.

Khaligh, A., A.M. Rahimi, A. Emadi, 2008. Modified pulse-adjustment technique to control dc/dc converters driving variable constant-power loads. IEEE Trans. Ind. Electron, 55(3): 1133-1146.

Villava, M.G. and E.F. Ruppert, 2008. Input-controlled buck converter for photovoltaic applications: modeling and design. In Proc. PEMD, 505-509.

Mohsen, R., L.W. Zhou, M. Nasser, 2010. Improvement of one-cycle controller response with a current mode controller. Journal of Power Electronics, 10(1): 461-467.

Huerta, S.C. P. Alou, J.A. Oliver, O. García, J.A. Cobos and A.M. Abou-Alfotouh, 2011. Nonlinear control for DC–DC converters based on hysteresis of the cout current with a frequency loop to operate at constant frequency. IEEE Trans. Ind. Electron, 58(3): 1036-1043.

Huerta, S.C., P. Alou, O. Garcia, J.A. Oliver, R. Prieto, J. Cobos, 2012. Hysteresis mixed-signal controller for high-frequency DC–DC converters operating at constant switching frequency. IEEE Trans. Power Electron, 27(6): 2690-2696.

Kapat, S. and P.T. Krein, 2012. Improved time optimal control of a buck converter based on capacitor current. IEEE Trans. Power Electron, 27(3): 1444-1454.

Goodfellow, S. and D. Weis, 1997. Designing power system around processors specifications. Electron. Design, 53–57.

Intel, 2005. AP-907 Pentium® III Processor Power Distribution Guidelines. Intel Application Notes.

Zhou, X., X. Zhang, J. Liu, P. Wong, J. Chen, H. Wu, L. Amoroso, F.C. Lee, D. Chen, 1998. Investigation of candidate for future microprocessors. In Proc. IEEE Applied Power Electron. Conf. (APEC). 1: 145–150.

Wei, J., P. Xu, H. Wu, F.C. Lee, K. Yao, M. Ye, 2001. Comparison of three topology candidates for 12 V VRM. In Proc. IEEE Applied Power Electronics Conf. (APEC), 1: 245–251.

Barrado, A., R. Vázquez, A. Lázaro, J. Pleite, J. Vaázquez, E. Olías, 2003. The fast response double buck converter (FRDB). In Proc. 33th Power Electronics Specialists Conf. (PESC'03), 1587–1592.

Åström, A. and T.H. Hägglund, 1995. New tuning methods for PID controllers, Proc. of the 3rd European Control Conference, 2456–62.