ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 4, Issue 2, February 2015**

# Modelling and Simulation of High Step-Up DC/DC Converter for On-Site Generation System

M.Saranya[1], S.Ramkumar[2], Dr.M.Muruganandam[3]

PG Student, Dept. of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India[1]

Assistant Professor, Dept. of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India[2]

Professor, Dept. of EEE, Muthayammal Engineering College, Rasipuram, Tamilnadu, India[3]

**ABSTRACT:** In this paper, to achieve high step-up voltage gain and high efficiency, a novel high step-up ratio using clamp-circuit in addition capacitor and diode along with the boost inductor is proposed. The capacitor gets charged during the switch-off period and discharged during the switch-on period by the energy stored in the inductor which leads to high voltage gain. The leakage-inductor energy of the coupled inductor is recycled with a passive clamp circuit. Thus, the voltage stress on the main switch is reduced. The switch with low resistance $R_{DS}$ is used to reduce the conduction loss which increases the efficiency. The operating principle and steady-state analyses are discussed in detail. Finally, a prototype circuit with 24-V input voltage, 48-V output voltage, is implemented in the laboratory to verify the performance of the proposed converter.

**KEYWORDS*:*** Clamp circuit, Coupled inductor, Fly-back converter, On-site generation (DG) system, high step-up.

## I. INTRODUCTION

In recent years, based on renewable energy sources on-site generation have rapidly developed. The On-Site Generation systems are composed of micro-source like fuel cells, photovoltaic (PV) cells, and wind power. But fuel cells and PV source are low-voltage sources to provide enough dc voltage for generating ac voltage. So PV cells can connect in series to obtain sufficient dc voltage, it is difficult to avoid the shadow effect. Hence, high step-up dc–dc converters are usually used as the front-end converters to step from low voltage to high voltage which are required to have a large conversion ratio, high efficiency, and small volume [1].

Theoretically, high step-up voltage gain with an extremely high duty cycle can be provided by the boost converter. In practice, due to the effect of power switch, rectifier diode, and the equivalent series resistance of the inductors and capacitors can limit the step-up voltage gain. Also, serious reverse-recovery and electromagnetic interference problems are caused by the extreme duty cycle operation [2-5].

To achieve a high step-up voltage gain the turn ratio of the transformer can be adjusted by some converters like the forward and fly-back converters.. However, high voltage spike and high power dissipation caused by the leakage inductor of the transformer will suffer the main switch. Although the non-dissipative snubber circuits and active-clamp circuits can be employed, due to the extra power switch and high side driver the cost is increased. [20-24].

Coupled-inductor technique is used by the converter to achieve a high step-up gain [8]. However, the leakage inductor leads to a voltage spike on the main switch which affects the conversion efficiency. For this reason, coupled inductor is used by the converter with an active-clamp circuit have been proposed [9],[10]. An integrated boost fly-back converter is proposed in which the secondary side of the coupled inductor is used as a fly-back converter [11], [12]. Thus, the voltage can be increased. Also, the energy of the leakage inductor is recycled and gives it to the output load directly which limits the voltage spike on the main switch. Additionally, by the turn ratio of the coupled inductor the voltage stress of the main switch can be adjusted. It has been proposed that the secondary side of the coupled inductor can be used as fly-back and forward converters [13], [14] to achieve a high step-up gain. Also, output-voltage stacking

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

are combined by the several converters to increase the voltage gain are proposed. Additionally, multiple coupled inductors are used by the high step-up boost converter with output stacking has been proposed [15-18].

This paper proposes a novel high step-up ratio and clamp-mode converter to achieve high step-up voltage gain and high efficiency. To achieve a high step-up voltage gain the proposed converter uses the capacitor that gets charged during the switch-off period and discharged during the switch-on period by the energy stored in the inductor [20]. However, high power loss and a high voltage spike on the switch may be caused by the leakage inductor of the coupled inductor. Thus, a passive clamping circuit is required to clamp the voltage level of the main switch and to recycle the energy of the leakage inductor.

## II.CIRCUIT CONFIGURATION OF CONVENTIONAL CONVERTER

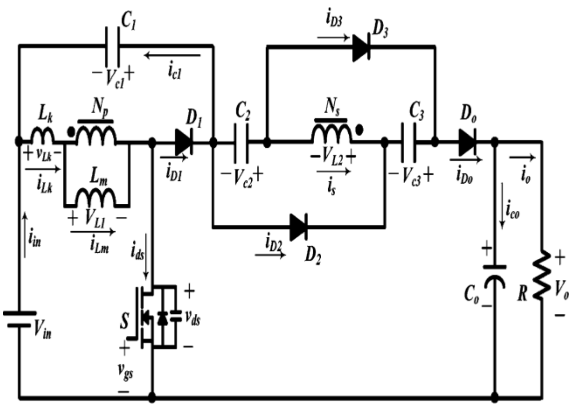

Fig 1.Circuit Diagram of Conventional Converter

Fig1.shows the circuit configuration of conventional converter which consists of dc input voltage $V_{in}$, main switch S, coupled inductors $N_p$ and $N_s$, one clamp diode $D_1$, clamp capacitor $C_1$, two capacitors $C_2$ and $C_3$, two diodes $D_2$and $D_3$,output diode $D_0$, and output capacitor $C_0$.It has magnetizing inductor $L_m$, leakage inductor $L_k$, and an ideal transformer. The leakage inductor energy of the coupled inductor is recycled to capacitor $C_1$, and thus, the voltage across the switch S can be clamped. The voltage stress on the switch is reduced significantly. Thus, low conducting resistance $R_{DS(ON)}$ of the switch can be used.

The original voltage –clamp circuit was first proposed in [1] to recycle the energy stored in the leakage inductor. Based on the topology, the conventional converter combines the concept of switched-capacitor and coupled inductor techniques. The switched-capacitor technique in [4] has proposed that capacitors can be parallel charged and series discharged to achieve a high step-up gain, Based on the concept, the conventional converter puts capacitors $C_2$ and $C_3$ on the secondary side of the coupled inductor. Thus, capacitors $C_2$ and $C_3$ are charged in parallel and discharged in series by the secondary side of the coupled inductor when the switch is turned off and turned on. Because the voltage across the capacitors can be adjusted by the turn ratio, the high step-up gain can be achieved significantly [25-26].Also, the voltage stress of the switch can be reduced. Compared to earlier-studies [3] – [7], the parallel-charged current is not inrush. Thus, the conventional converter has low conduction loss. Moreover, the secondary-side leakage inductor of the coupled inductor can alleviate the reverse-recovery problem of diodes, and the loss can be reduced. In addition, the conventional converter adds capacitors $C_2$ and $C_3$ to achieve a high step-up gain without an additional winding stage of the coupled inductor. The coil is less than that of other coupled inductor converters.

The main operating principle is that, when the switch is turned on, the coupled inductor induced voltage on the secondary side and magnetic inductor $L_m$ is charged by$V_{in}$. The induced voltage makes$V_{in}$,$V_{C1}$,$V_{C2}$, $V_{C3}$release energy to the output in series. The coupled inductor is used as a transformer in the forward converter. When the switch is turned off, the energy of magnetic inductor $L_m$ is released via the secondary side of the coupled inductor to charge capacitors $C_2$ and $C_3$ in parallel. [27-29],

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

## III.BLOCK DIAGRAM

Fig.2 shows the block diagram of proposed converter. In the proposed converter, an integrated boost fly-back converter is presented in which the secondary side of the coupled inductor. The voltage stress of the main switch can be adjusted by the turn ratio of the boost inductor. A high step-up boost converter that uses multiple coupled inductors. Less components are used to achieve the high step up voltage end.

The fly back converter is used in both AC/DC and DC/DC conversion with galvanic isolation between the input and any outputs. More precisely, the fly back converter is a buck-boost converter with the inductor split to form a transformer, so that the voltage ratios are multiplied with an additional advantage of isolation.

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

From the DC Source the DC supply is fed to Fly back converter. In fly-back converter the DC supply is converted into boost DC supply. The leakage current present in the primary side of fly-back converter is converted into useful energy in output side. Now the boosted output is again increased by connecting voltage lifter. Voltage lifter output is directly connected to load. The output of voltage lifter is taken as feedback for PID controller. The PID controller produces a corrected PWM for fly-back converter. The synchronous rectification operation of fly-back converter which helps to increase the efficiency.

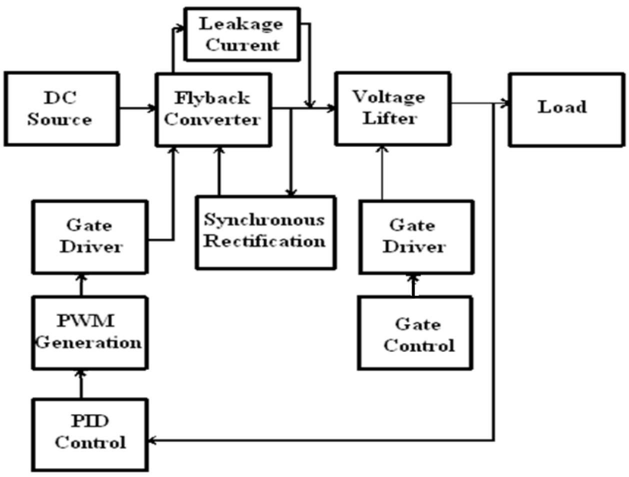


Fig.2. Block Diagram for High Step Up Dc-Dc Converter

## IV. CIRCUIT CONFIGURATION OF PROPOSED CONVERTER

Fig3.shows the circuit topology of the proposed converter, which is composed of dc input voltage *V*in, main switch *S*, inductor *L*, one clamp diode *D*1, clamp capacitor *C*1, output diode *Do* and output capacitor *Co*. The leakage inductor energy of the inductor is recycled to capacitor *C*1. Thus, the voltage across the switch *S* can be clamped. The voltage stress on the switch is reduced significantly by the low conducting resistance *R*DS(ON) of the switch can be used.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

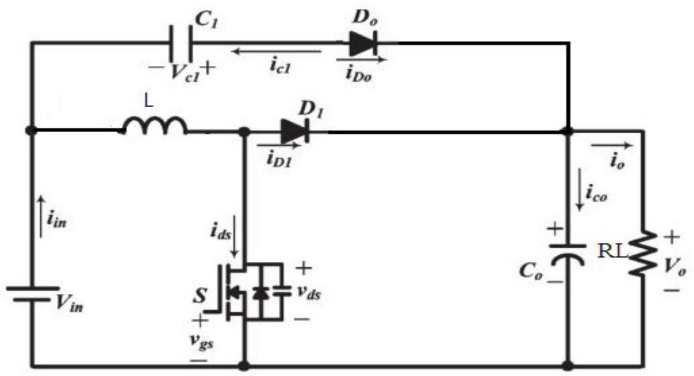


Fig3.Circuit configuration of the proposed converter

The original voltage-clamp circuit was used to recycle the energy stored in the leakage inductor. Based on the topology, the proposed converter combines the concept of switched-capacitor and coupled-inductor techniques. The switched-capacitor technique has proposed that capacitors can be charged and discharged to achieve a high step-up gain. Based on the concept, the proposed converter puts capacitor$C1$ in parallel with the inductor. Thus, capacitor is charged and discharged by the inductor when the switch is turned off and turned on. Because the voltage across the capacitors can be adjusted by the turn ratio, the high step-up gain can be achieved significantly. Also, the voltage stress of the switch can be reduced. Compared to earlier studies, the parallel-charged current is not inrush and also the proposed converter reduces the number of components. Thus, the proposed converter has low conduction loss. Moreover, leakage inductor can alleviate the reverse-recovery problem of diodes, and the loss can be reduced.

The main operating principle is that, when the switch is turned on, the coupled-inductor-induces the voltage. The induced voltage makes $V$in,$VC$1release energy to the output in series. The inductor is used as a forward converter. When the switch is turned off, the energy of the inductor Lis used to charge capacitor$C$1. The coupled inductor is used as a transformer in the flyback converter.

From the conventional converter, the proposed converter reduces the number of capacitors and diodes. And also instead of coupled inductor the proposed converter uses the single inductor (boost inductor) which increases the voltage level. So, conduction loss can be reduced and also efficiency can be improved. Instead of R load, the proposed converter uses the RL load.

## V.OPERATING PRINCIPLE OF THE PROPOSED CONVERTER

### Operation of the proposed converter

This section presents the operating principle of the proposed converter. The following analysis contains the explanation of the power flow direction of each mode. There are three operating modes in the proposed converter. The operating modes are described as follows.

1) Mode I [t0, t1]: During this time interval, Sis turned off. Diodes D1 is turned off and Diode D0 is turned on. When supply is given the capacitor C1 gets charged by $V_{in.}$The capacitor is charged during the switch- off period. Output capacitor C0 provides its energy to load RL. When current iD0 becomes zero at t = t1, this operating mode ends.

2) Mode II [t1, t2]: During this time interval, switch S gets turned on. In this mode also diodeD1 is turned off, and Do is turned on. The inductor L is charged by$V_{in}$. During switch-on period capacitor C1 gets discharged and inductor L gets charged. The input supply 24V is given to the load through the capacitor C1 and diode D0. Due to boost inductor L the input voltage get increased and it is given to the load. Output capacitor Co provides its energy to load RL. This operating mode ends when switch S is turned off at t = t2.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 4, Issue 2, February 2015**

3) Mode III [t2, t3]: During this time interval, S is turned off. Diodes D1, Do are turned on. During this mode the capacitor C1 again gets charged and inductor L gets discharged. The increased input voltage due to boost inductor L is given to the load through the diode D1. Output capacitor Co provides its energy to the load RL. When current $i_{D1}$becomes zero at t=$t_3$ , this operating mode ends.

## VI. DESIGN AND EXPERIMENT OF THE PROPOSED CONVERTER

To verify the performance of the proposed converter, a prototype circuit is implemented in the laboratory. The specifications are as follows:
1) Input dc voltage Vin: 24 V;
2) Output dc voltage Vo: 48 V;
3) Maximum output power: 58 W;
4) Switching frequency: 50 kHz;
5) Output dc current$I_o$:1.2A

## VII.SIMULATION CIRCUIT

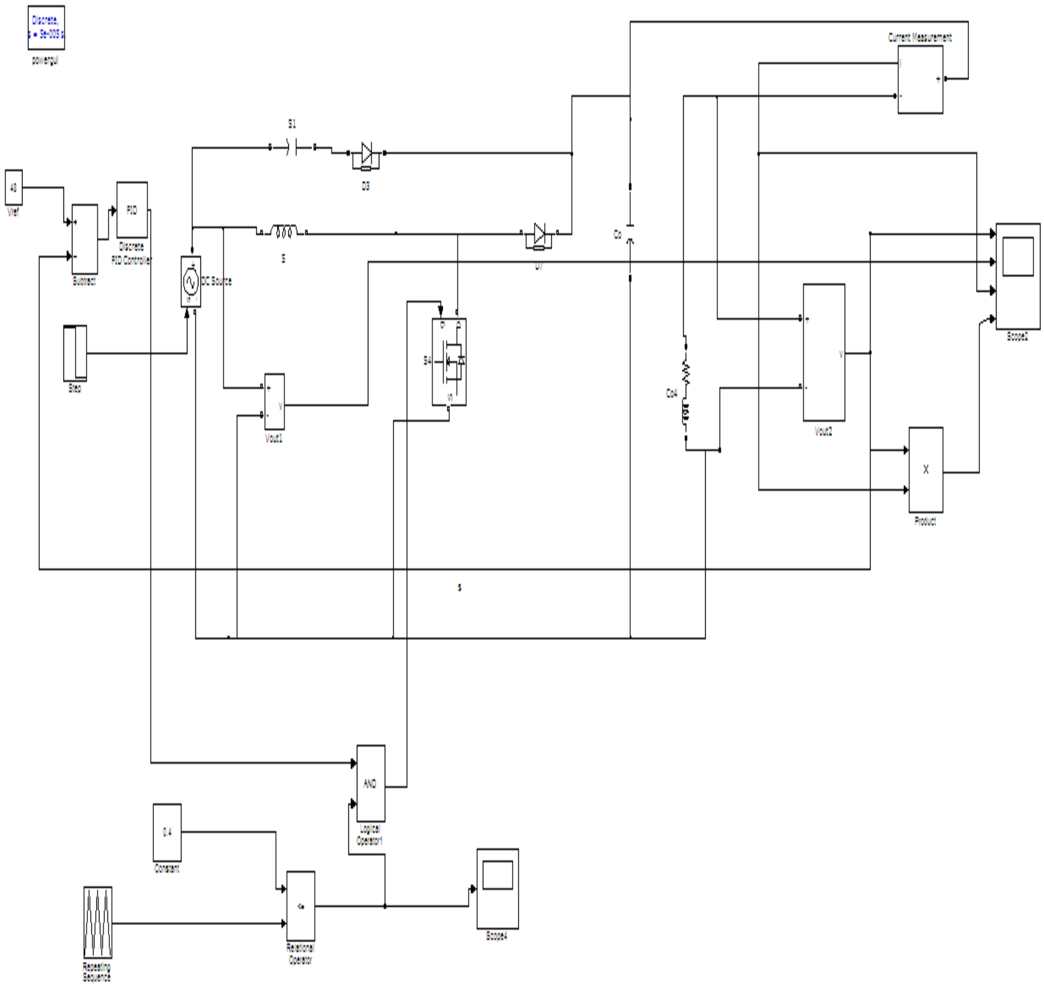

Fig .4.By using the MATLAB 2010, the proposed DC-DC Converter is developed.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

**International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering**

*(An ISO 3297: 2007 Certified Organization)*

**Vol. 4, Issue 2, February 2015**

## VIII.SIMULATION WAVEFORM

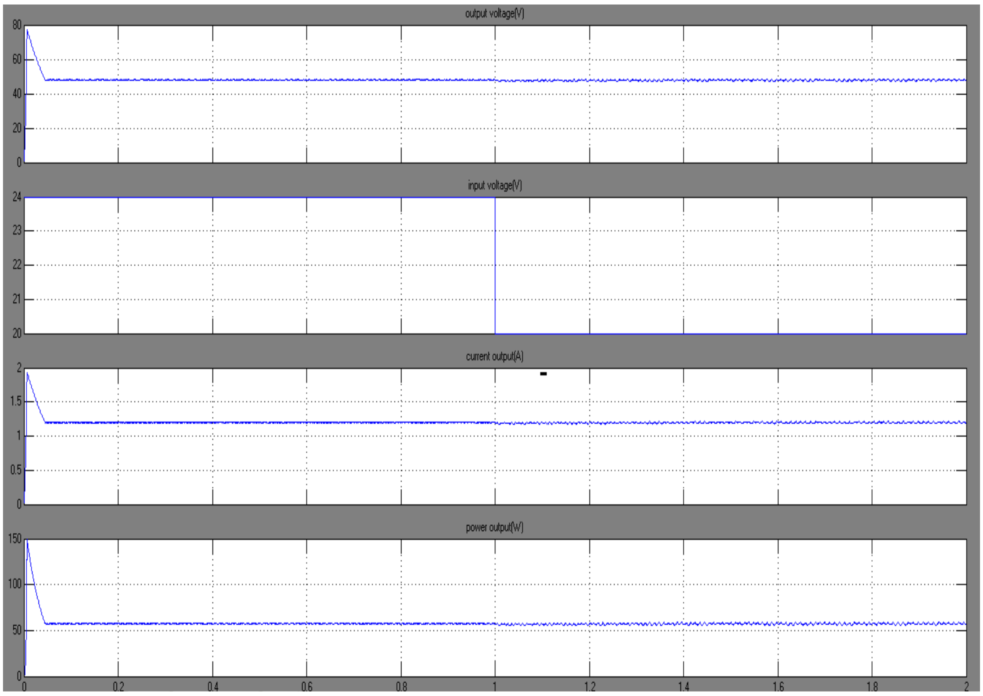


Fig.5. Simulation Results

## IX.CONCLUSION

This paper has proposed a novel high step-up dc–dc converter for DG systems. By using the capacitor charged in parallel and discharged in series by the coupled inductor, high step-up voltage gain and high efficiency are achieved. The steady-state analyses have been discussed in detail. Finally, a 24- to48-V, 58-W prototype circuit of the proposed converter is put into operation in the laboratory. The experimental results have confirmed that high efficiency and high step-up voltage gain can be achieved. Thus, a switch with low voltage ratings and low ON-state resistance RDS(ON) can be selected.

## REFERENCES

1. Q. Zhao and F. C. Lee, "High-efficiency, high step-up dc–dc converters," IEEE Trans. Power Electron., vol. 18, no. 1, pp. 65–73, Jan. 2003.
2. R. J. Wai, C. Y. Lin, C. Y. Lin, R. Y. Duan, and Y. R.Chang, "Highefficiency power conversion system for kilowatt-level stand-alone generationunit with low input voltage," IEEE Trans. Ind. Electron., vol. 55,no. 10, pp. 3702–3714, Oct. 2008.
3. M.Muruganandam, M.Madheswaran, "Simulation and Implementation of Generalized Hybrid Intelligent Controllers for Chopper fed DC Series Motor" Published in International Journal of Wulfenia, Volume 19, Issue 12, December 2012, Page(s):313-335. ISSN: 1561-882X
4. O. Abutbul, A. Gherlitz, Y. Berkovich, and A. Ioinovici, "Step-upswitching-mode converter with high voltage gain using a switchedcapacitorcircuit," IEEE Trans. Circuits Syst. I, Fundam. Theory Appl.,vol. 50, no. 8, pp. 1098–1102, Aug. 2003.
5. B. Axelrod, Y. Berkovich, and A. Ioinovici, "Switched-capacitor/switched-inductor structures for getting transformerless hybrid dc–dcPWMconverters," IEEE Trans. Circuits Syst. I, Reg. Papers, vol. 55, no. 2,pp. 687–696, Mar. 2008.
6. M.Madheswaran and M.Muruganandam, "Simulation and Implementation of PID-ANN Controller for Chopper Fed Embedded PMDC Motor" Published in ICTACT Journal On Soft Computing, Volume 2, Issue 3, April 2012 pp 319-324. ISSN: 2229-6956(Online)
7. F. L. Luo, "Six self-lift dc–dc converters, voltage lift technique," IEEETrans. Ind. Electron., vol. 48, no. 6, pp. 1268–1272, Dec. 2001.
8. F. L. Luo and H. Ye, "Positive output super-lift converters," IEEE Trans.Power Electron., vol. 18, no. 1, pp. 105–113, Jan. 2003.
9. Ramkumar.S, Venkatesan C. V and Saravanan.S, "Direct Torque Control for Three Phase Induction Motor without AC Phase Current Sensors," IJERT Vol. 2 Issue12, ISSN: 2278-0181, December - 2013.
10. F. L. Luo and H. Ye, "Positive output multiple-lift push–pull switchedcapacitorLuoconverters," IEEE Trans. Ind. Electron., vol. 51, no.3,pp. 594–602, Jun. 2004.
11. R. J. Wai and R. Y. Duan, "High-efficiency dc/dc converter with highvoltage gain," Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 152, no. 4,pp. 793–802, Jul. 2005.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 2, February 2015

12. M.Muruganandam and M.Madheswaran, "Hybrid PID-ANN Controller for Closed Loop Control of Chopper fed DC Series Motor" has been presented the Second International Conference on Interdisciplinary Research and Development, INRIT2012, 1st June 2012, Thailand.
13. C.Nagarajan and M.Madheswaran - 'Performance Estimation of LCL-T Resonant Converter with Fuzzy / PID Controller'- International Journal of Computer and Electronic Engineering (IJCEE), Vol.2 (3), pp.534-542, June 2010
14. B. R. Lin and F. Y. Hsieh, "Soft-switching zeta–flyback converter with a buck–boost type of active clamp," IEEE Trans. Ind. Electron., vol. 54, no. 5, pp. 2813–2822, Oct. 2007.
15. M. Muruganandam, M. Madheswaran, "Experimental verification of chopper fed DC series motor with ANN controller" Published in International Journal of Frontiers of Electrical and Electronic Engineering in China, (Springer Publication) Volume 7, Issue 4, December 2012, pp 477-489. ISSN: 2095-2732 (print) 1673-3584 (Online)
16. T. F. Wu, Y. S. Lai, J. C. Hung, and Y. M. Chen, "Boost converter withcoupled inductors and buck–boost type of active clamp," IEEE Trans. Ind.Electron., vol. 55, no. 1, pp. 154–162, Jan. 2008.
17. K. C. Tseng and T. J. Liang, "Novel high-efficiency step-up converter,"Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 151, no. 2, pp. 182–190,Mar. 2004.
18. C.Nagarajan and M.Madheswaran - 'Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis"- *Springer, Electrical Engineering*, Vol.93,March 2011.
19. K. C. Tseng and T. J. Liang, "Analysis of integrated boost–flyback stepupconverter," Proc. Inst. Elect. Eng.—Elect. Power Appl., vol. 152, no. 2,pp. 217–225, Mar. 2005.
20. R. J. Wai and R. Y. Duan, "High step-up converter with coupledinductor,"IEEE Trans. Power Electron., vol. 20, no. 5, pp. 1025–1035,
21. Mr.S.Saranraj, Mrs.A.Sasipriya, S.Ramkumar, M.Muruganandam "Voltage Controlled PFC SEPIC Converter Based PMBLDCM Drive for Air-Conditioners UsingFuzzy Controller" JAIR Vol.3, Issue 11, ISSN: 2278-7844, Nov 2014
22. R. J. Wai, L. W. Liu, and R. Y. Duan, "High-efficiency voltage-clampeddc–dc converter with reduced reverse-recovery current and switchvoltagestress," IEEE Trans. Ind. Electron., vol. 53, no. 1, pp. 272–280,Feb. 2005.
23. J. W. Baek, M. H. Ryoo, T. J. Kim, D. W. Yoo, and J. S. Kim, "Highboost converter using voltage multiplier," in Proc. IEEE IECON, 2005,pp. 567–572.
24. G. V. T. Bascope, R. P. T. Bascope, D. S. Oliveira, Jr., S. A. Vasconcelos,F. L. M. Antunes, and C. G. C. Branco, "A high step-up dc–dc converterbased on three-state switching cell," in Proc. IEEE ISIE, 2006,pp. 998–1003.
25. S. K. Changchien, T. J. Liang, J. F. Chen, and L. S. Yang, "Novel highstep-up dc–dc converter for fuel cell energy conversion system," IEEETrans. Ind. Electron., vol. 57, no. 6, pp. 2007–2017, Jun. 2010.
26. C Nagarajan, M Muruganandam, D Ramasubramanian, "Analysis and Design of CLL Resonant Converter for Solar Panel-battery Systems", International Journal of Intelligent Systems and Applications (IJISA), Volume 1, December 2012 pp 52-58.
27. M.Kirubavathi, G.Dineshkumar and M.Muruganandam, "Fault Current and Over Voltage Limitation in a Distribution Network with Distributed Generation Units through Superconduction Fault Current Limiter" Published in International Journal of Engineering Research and Technology, Volume 3, Issue 11, November 2014, Page(s):1442-1445, ISSN: 2278-0181
28. C.Nagarajan and M.Madheswaran - 'Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter' - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.
29. Muruganandam, M, Thangaraju I and Madheswaran, M. "Simulation and Implementation of an Embedded Hybrid Fuzzy Trained Artificial Neural Network Controller for Different DC Motor" Published in International Journal of Engineering and Technology, Vol. 6, Issue 1, pp. 315-332 February 2014. ISSN:0975-4024 (Online)