Implementation of MVDC distribution system using quadratic boost converter

PARANTHAGAN.B[1], AARTHY A[2], AKHILA B[3], GAYATHRI N[4], SRILAXMIE C[5]
ELECTRICAL AND ELECTRONICS ENGINEERING
SARANATHAN COLLEGE OF ENGINEERING, TRICHY, TAMILNADU, INDIA

***Abstract*— Due to increasing number of power generation units and load devices operating with direct current (DC) at distribution level, there is a potential benefit of building a DC distribution system. However, there are challenges in implementing a DC distribution system mainly the standardization. The dominance of AC was facilitated by the ease of transforming AC electrical energy to different voltage levels through the AC transformer, needed for efficient transportation over long distances. However, the advances in power electronics nowadays allow for an equally simple transformation of DC voltages. Simulation of buck converter and quadratic boost converter (QBC) for the required DC output value has been executed in MATLAB/SIMULINK environment.**

.

***Index Terms*—DC distribution, quadratic boost converter, buck converter.**

I. INTRODUCTION

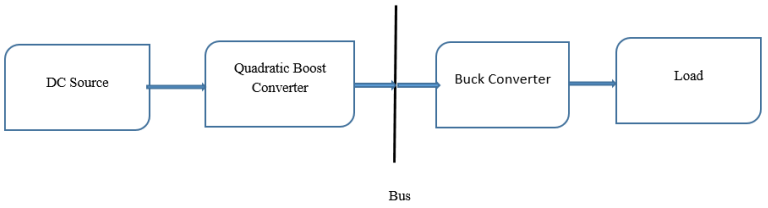
In the late 19th century Thomas Edison and George Westinghouse concerned the relative merits of AC and DC distribution system. The first electric power transmission system was made by DC. Despite that it was difficult to transfer power over long distances. Hence the AC system which transfer high voltage obviously using transformers, was selected as standard power system. Since then AC distribution won favour and has entangled with our electrical power system

The technology is revamping every day that eventually leads to increased usage of loads. India is running out of energy resources as the peak demand is found to be 11 %[7]. This motivates the power grid to install renewable energy based generating units. The power delivered by the renewable resources is DC which is converted to AC as the conventional transmission system operates in AC. This AC power is again converted to DC as many home appliances and commercial buildings needs DC power.

In the recent years, due to the advancements in power electronics technology and power semiconductor technology, the limitations in DC distribution system has been gradually overcome[1]. Thus, making the DC technology appears to emerge again. There are some technical challenges in implementing DC distribution at higher level voltages due to unavailable of DC standarad voltages. Thus, the prototype of DC distribution system at low voltage level has been implemented by using quadratic boost converter and buck converter[3]. Both the simulation and hardware prototype has been demonstrated. Simulation results of the study shows that DC system has higher efficiency and reduced losses as compared to traditional AC system.

II.BLOCK DIAGRAM

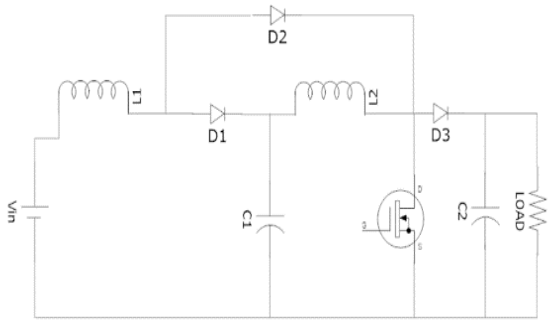
The entire block consists of source, quadratic boost converter, buck converter and a load. The source used is 48V DC source. Quadratic converter is a dc-dc converter which steps up the voltage to 4 to 6 times the input voltage. In this project 48V is stepped up to 300V.The buck converter is a dc-dc converter which steps down the input voltage to a desired value according to the duty cycle specified. The input voltage of the buck converter is 300V which is stepped down to 48V.Any kind of DC load of 100W, 48V can be used. Here lighting load is used.



III.QUADRATICBOOST CONVERTER

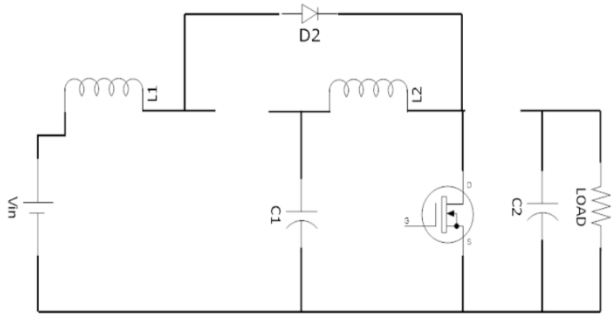
Quadratic boost converter is one of the emerging power electronics converter where the voltage boosts till 4 to 6 times the input voltage, normal boost converter boosts 2 times the input voltage.

The circuit consists of inductors, capacitors, diodes and a switch. The input voltage source can be any kind of DC voltage source The output voltage is measured across the capacitor C2. There are two modes of operation based on ON and OFF states of switch.



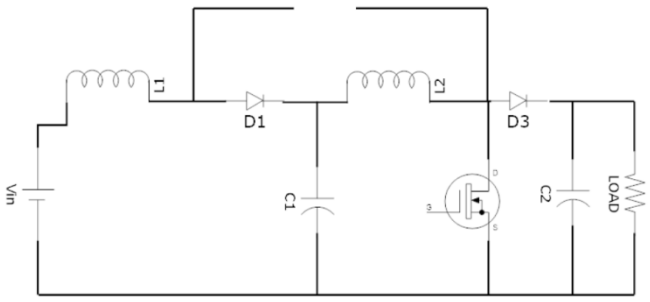
MODE 1

When switch s is turned on D2 is forward biased, whereas D1 and D3 are reverse biased.currents are supplied to L1 and L2 by Vin and C1 respectively.



MODE 2

In this mode D1 and D3 are forward biased, whereas D2 is reverse biased. L1 and L2 are charging C1 and C2 respectively.



QUADRATIC BOOST CONVERTER

The below figure shows the diagram of Quadratic Boost Converter and designed for 48/300 V.

$D = 1-((V_{in}/V_o)^{\wedge}(-1/2))$

$=0.6$

$I_{L1avg}=I_o/(1-D)^2$

$=3.125$ A.

$I_{L2avg}=I_o/(1-D)$

$=1.25$ A

$I_{L1}=20\%$ of I_{L1avg}

$=0.625$ A

$I_{L2}=20\%$ of I_{L2avg}

$=0.25$ A.

$I_{L1max}=(I_{L1}/2)+I_{L1avg}$

$=3.437$ A.

$I_{L2max}=(I_{L2}/2)+I_{L1avg}$

$=1.375$ A.

INDUCTANCES VALUES

$L_1=(V_{in}*D)/(I_{L1}*f)$

$=5.76$ mH

$L_2=(V_{in}*D)/(I_{L2}*f*(1-D))$

$=0.036$ H

CAPACITANCE VALUES

$C_1=(I_o*D)/((1-D)*V_{C1}*f)$

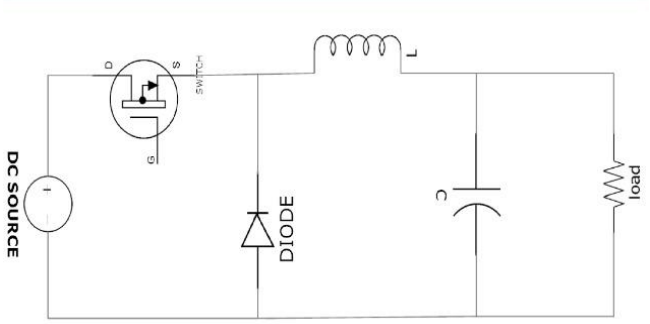
$=1.5625*10^{\wedge}-5$ F

$C_2=(I_o*D)/(V_{C2}*f)$

$=2.5*10^{\wedge}-6$ F

IV. BUCK CONVERTER

Buck converter is a switch mode DC-DC electronic converter in which output voltage will be transformed to level less than the input voltage .It is also called as step down converter. The name step down converter comes from the fact that analogous to step down transformer the input voltage is stepped down to a level less than input voltage. By law of conservation of energy the input power has to be equal to output power.



Buck converter is the converter in which the inductor in the input circuit resists sudden variation in input current .when the

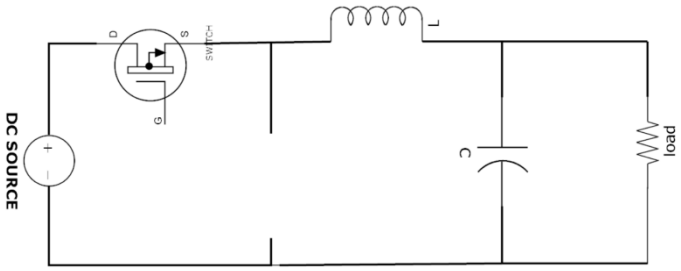
switch is ON the inductor stores energy in the form of magnetic energy and discharges it when the switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage.

The circuit consists of an inductor, a capacitor, a diode and a switch.

This circuit can be operated in two modes based on ON and OFF states of switch.

MODE 1

When switch is in ON state the diode will be open circuited since it is in reverse biased condition. During this state the inductor gets charged by V_{in} thus closing the circuit through capacitor C.



MODE 2

In this mode the switch is in OFF state the diode will be forward biased. The inductor now discharges through diode and capacitor C.

$D = V_o/V_{in}$

$= 48/300$

$= 0.16$

I_L=30% of I_{Load}

=0.25 A.

INDUCTANCE VALUE

$L = V*(T/I_L)$

$(V=V_{in}-V_o)$

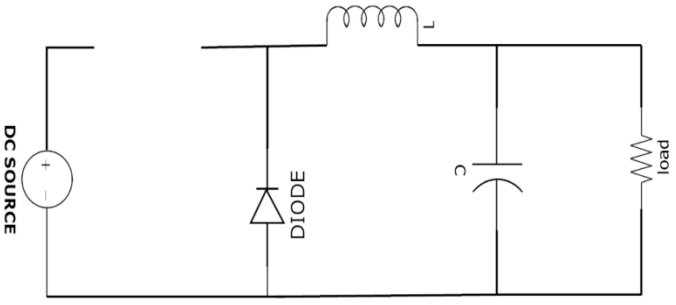
=0. 02016H.

CAPACITANCE VALUE

$C = I_L/(8*f*V_c)$

$(V_c$=2% of $V_o)$

=4.069*10^-6 F



V. SIMULATION

In our project we designed simulation using MATLAB SIMULINK for DC distribution system using Buck Converter and Quadratic Boost Converter and made comparison with AC distribution system. We designed for 1KW system and scale down for 110 W for hardware.

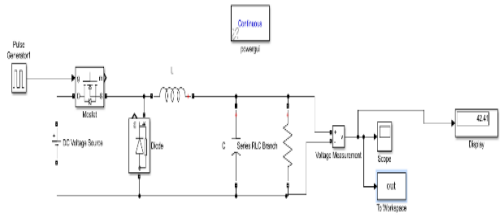


Figure 1: buck converter simulation diagram

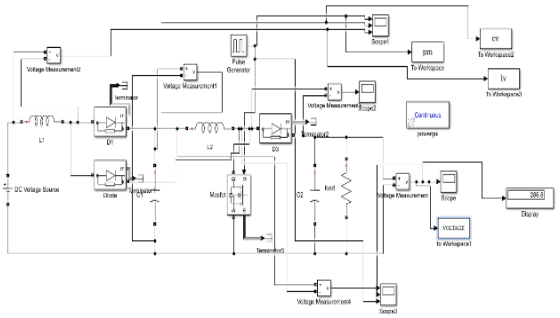


Figure 2: Simulation of Quadratic boost converter

DC DISTRIBUTION SYSTEM

This simulation diagram shows the model of DC distribution system using Quadratic boost converter and buck converter by neglecting the losses in the simulation. Using DC source generating 48 V and boosting to 300 V using Quadratic boost converter and distributed to load side stepped down from 300 V to 48 V using Buck converter. The load considered here is DC loads like LED lamps, computers.

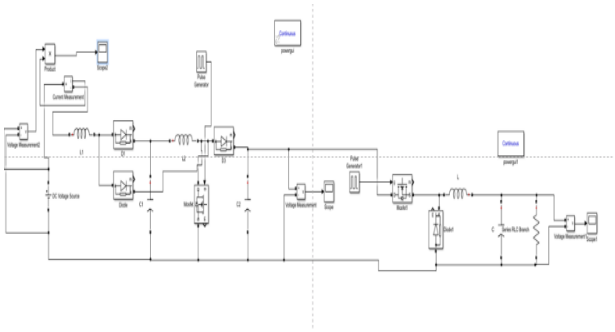


Figure 3: Simulation of DC distribution system

VI.SIMULATION RESULTS AND DISCUSSION

The simulation results shown here for an ideal case (i.e) neglecting losses. For hardware consider the losses and choose the converters for higher efficiency operation. Simulation model shows the efficiency of DC distribution over the AC distribution system.

In Figure 4, at the starting period of time, there are some transients till 0.05 seconds after which it get settled and provide voltage of 270 V.

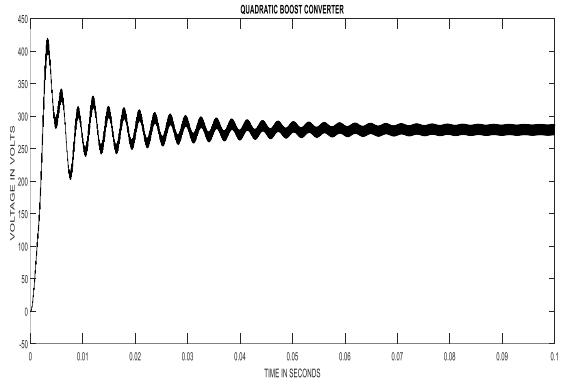


Figure 4:Waveform of quadratic boost converter

In Figure 5, time period of transients is very less and hence provides voltage of 46V at around 0.005s.

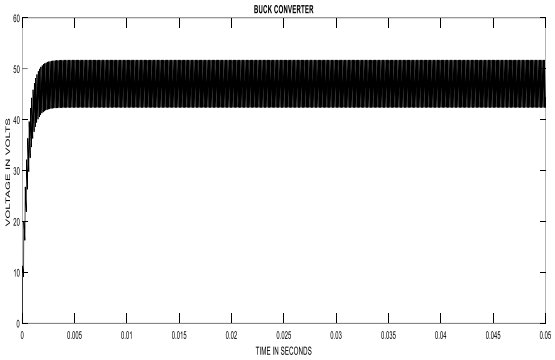


Figure 5: Waveform of buck converter

In Figure 6, due to the interconnection of quadratic boost converter and buck converter the effect of transient in the system is much lesser as compared with quadratic boost converter alone the output gets stabilized in short span of time. This helps the distribution system to feed the load efficiently.

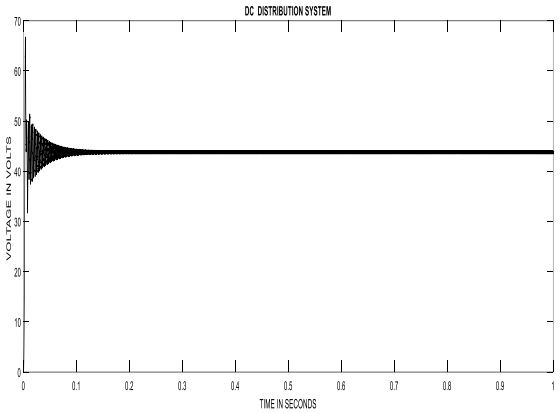


Figure 6:Waveform of DC distribution systems

CONCULSION

DC is an emerging technique. Due to development of power electronics technology, converters will acts like step up and step down transformer, that will greatly help in distribution system .Developed countries like China, started to implement DC distribution system in a testing model for consumers applications. If certain disadvantages like high cost of DC components , Protection issues are cleared. Surely DC will rule the future electrical systems

REFERENCES

[1] Toward the Universal DC Distribution System
Laurens Mackay, Nils H. van der Blij, Laura Ramirez-Elizondo & Pavol Bauer,28 March 2017.

[2] Coltman, J. W., "The transformer [historical overview]," IEEE,
Ind. Appl. Mag., Vol. 8, No. 1, pp. 8–15, January 2002.

[3]Low Voltage DC Distribution System, Asian Power 2Electronics Journal, Vol. 8, No. 3, Dec 2014 .

[4] S. Luo, and I. Batarseh, "A review of Distributed power systems Part 1: DC distributed power system", IEEEAerosp. Electron.5-Syst. Mag., vol. 21, no. 6, Jun. 2006, pp, 5-14.

[5] D. Boroyevich, I. Cvetkovic, D. Dong, R. Burgos, F. Wang, F. C. Lee, "Future electronic power distribution system-a contemplative view", OPTIM' 2010, pp. 1369 – 1380.

[6]Direct Current Distribution Systems for Residential Areas Powered by Distributed Generation *By FaizanDastgeer*

[7] Performance analysis of power distribution systems with weakly grid connected rural homes in India
R.K. Chauhan a ,∗, K. Chauhan b, *Energy and buildings* 307-316, *May,2018.*

[8] K. Garbesi, V. Vossos, and H. Shen, "Catalog of DC appliances and power sys- tems,"October 2011.

[9] Shamsi, P.; Fahimi, B., "Stability Assessment of a DC Distribution Network in a Hybrid Micro-Grid Application," *IEEE Trans. on Smart Grid* , vol.5, no.5, pp.2527,2534, Sept. 2014

[10] R.J.C. Pinto, S.J.P.S. Mariano, M.D.R.A. Calado, Power quality experimental anal- ysis on rural home grid-connected PV Systems, Int. J. Phtotenergy 2015 (June) (2015) 1–8. http://dx.doi.org/10.1155/2015/791680) .

[11] Dong, D.; Cvetkovic, I.; Boroyevich, D.; Zhang, W.; Wang, R.; Mattavelli, P., "Grid-Interface Bidirectional Converter for Residential DC Distribution Systems—Part One: High-Density Two-Stage Topology," *IEEE Trans. on Power Electron.*, vol.28, no.4, pp.1655,1666, April 2013

[12] B. Morton, I. M. Y. Mareels, "The prospects for dc power distribution in buildings", AUPEC'99.

[13] H. Pang; E. Lo, B. Pong, "Dc electrical distribution systems in buildings", ICPESA '06, pp. 115-119.

[14] K. Engelen, J, Dridsen, et al., "Small-scale residential dc distribution systems", 3rd IEEE Benelux Young Reasearchers Symposium in Electrical Power Engineering, Ghent (2006-4), pp. 1-7.

[15] F. Dastgeer, A. Kalam, "Evolution of dc distributed power system stability",*International Review of Electrical Engineering*, part B, vol. 5, pp.652-662, April, 2010

[16] F. Dastgeer, A. Kalam, "Efficiency comparison of DC and AC distribution systems for distributed generation", *Australasian Universities Power Engineering Conference*, pp. 1-5, 2009.