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Additional Series Positive Output Superlift LUO Converter using Particle Swarm Optimization

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ABSTRACT : Due to the advancement in the semiconductor technology DC-DC converters are gaining the importance in several industrial applications. They form the core of the switched mode power supplies used in real time applications. But the conventional DC -DC converter contains the voltage ripples due to the effect of the parasitic elements which is undesirable. The derived topologies of DC –DC converters from the conventional pumps eradicates this effect. In this paper the superlift LUO DC-DC converter will be presented which can replace the conventional converters. The effect of the parasitic elements is eradicated in superlift converter and range of the boosting the voltage level is high which will reduce the charging time and can be applicable for charging of o electric vehicles. The optimized proportional and integral controller using particle swarm optimization is applied to the presented converters.

Key words: DC-DC converter, superlift luo converter, proportional and integral controller ,Particle Swarm Optimization

I. INTRODUCTION

Due to the advancement in the semiconductor technologies which form the core part of various vehicular applications ,aerospace, Photovoltaic systems etc ,DC-DC converters are gaining extreme importance. One of the main purpose DC –DC converters to create a high voltage DC link. The electronic pumps which have the DC –DC converter as it its core element are broadly categorized as fundamental pumps, derived pumps, transformer-type pump and super lift pumps. The fundamental pumps are generally buck,boost and buck-boost pumps and all other derived from the fundamental[1]. In basic topologies there is the effect of the parasitic elements but by using the advance pumps this effect can be minimized and voltage levels can be changed to more significant level. the Super lift pumps are further classified as Positive super Luo-pump, Negative super Luo-pump, Positive push-pull pump, Negative push-pull pump, Double/Enhanced circuit (DEC) eradicates the effect of the parasitic elements to a great extent[2]. Each of this topology is also further divided into various subcategories.

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The Positive Output Luo converter which is basically a boost converter and have a capability to enhance the voltage by the considerable amount is presented here. The conventional boosts converter contains the ripple in the output voltage due to the effect of the inherent
parasitic elements[3]. But this paper presents the topology of the boost converter in which the effect of the parasitic elements is being reduced sufficiently and high levels of the voltage are obtained .Thus Luo converter are very beneficial for providing
the DC link required in the Electric vehicle as it will reduce the charging time.

II. POSITIVE OUTPUT SUPER LIFT LUO CONVERTERS

Based on the number of switching devices and the enhancement in the voltage level[4] The positive out Luo converters are further classified as
Main series: It consist of one main switching device ,n number of inductor , 2n number of capacitor and (2n-1)diodes, where n =1,2 ,3….for elementary circuit, relift ,triple lift so on.
Additional Series: In this series there is one switching device, for nth stage n number of inductor,2(n+1) capacitor (3n+1) diodes
Enhanced Series-In This type of series there is one switch, the nth stage there will be n inductors,4 capacitor and (5n-1) diodes.
Re –Enhanced Series: In this circuit topology there is one switch ,for nth stage number of inductors are n, there are 6 capacitors and (7n—1)diodes. Multiple (j) Enhanced series-this topology has one switch and for nth stage of the converter there will be n inductors,2(1+j)n capacitors and [(3+2j)n—1] diodes.
Additional Series :This series topologies have one switch, the number of inductors for the nth stage is n,2(n+1) capacitors are required and (3n+1) diodes will be used.
In this paper Elementary topology , Re lift converter and triple lift topologies of Enhanced series Luo converter in the closed loop using different closed loop control techniques is being discussed.

III. ADDITIONAL SERIES CONVERTER

The additional series converter are further classified as elementary P/O superlift converter, Re-lift converter and triple lift converters
The additional series converter is obtained by adding double enhanced circuit(DEC)[4] to the main series converter.

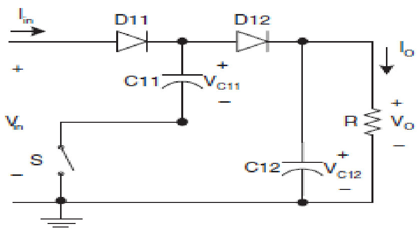

Figure 1 –Double enhanced circuit

The DEC circuit is obtained using two diodes and two capacitors as shown in figure 1.

A. Elementary Topology

In this type of the converters there are two capacitors, one inductor, one switch and two DEC. The main circuit and the topologies during

dynamic conditions are shown in the figure 2(b) and figure 2(c) while figure 2(a) [5] is the main circuit of the elementary additional series converters .

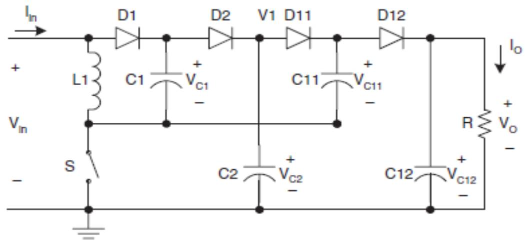

Figure 2(a)

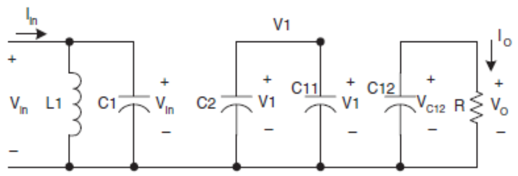

Figure 2(b)

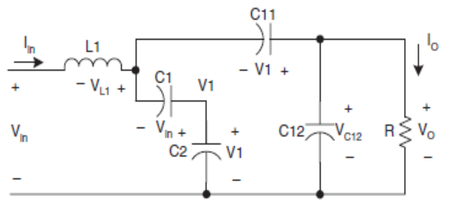

Figure 2(b)

Figure 2 (a) Topology of Elementary additional series converter,2(b) Elementary converter in turn On Mode,2(c) elementary additional series in turn off mode.

As input Vin is applied the capacitor C1 us charged upto the voltage Vin and the capacitors C11 and C2 to the voltage V1 and inductor current rises during the interval of turn on kt. During turn off times voltage is diminished to $-(V_o\ -2V_{in})$ during (1-kt) interval i.e turn off[6]. Therefore,

$$V_1 = \frac{2-k}{1-k}V_{in} \qquad (1)$$

$$V_{L1} = \frac{k}{1-k}V_{in} \qquad (2)$$

Output voltage

$$V_o = V_{in} + V_{L1} + V_1 = \frac{3-k}{1-k}V_{in} \qquad (3)$$

Thus voltage transfer gain is given by

$$G = \frac{V_o}{V_{in}} = \frac{3-k}{1-k} \qquad (4)$$

B. Re lift Additional Circuit

When the DEC circuit is amended in the Re lift topology of main series positive output Luo converters then re-lift additional topology is derived as shown in the figure 3.

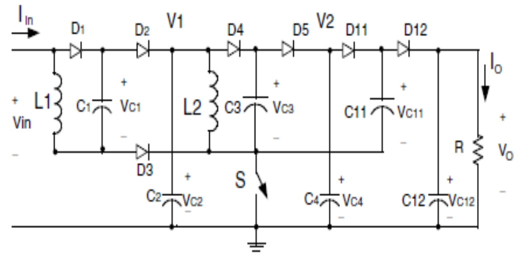

Figure 3(a)

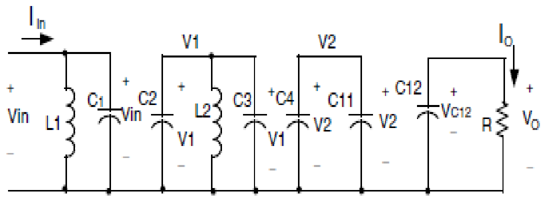

Figure 3(b)

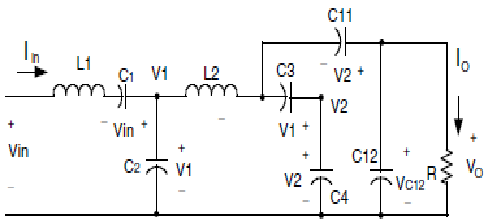

Figure 3(c)

Figure 3 (a) Topology of Re-lift additional series converter,3(b) converter in turn On Mode,3(c)Converter in turn off mode.

When switch is turned on then the current ,the capaicter C_1 gets charged to the voltage V_{in} and across C_2 voltage is given by

$$V_1 = \frac{2-k}{1-k}V_{in} \qquad (5)$$

C_3 holds the voltage V_1 and C_4 &C_{11} acquire voltage V_2. During the interval kT current rises ad voltage increases to V_1 and in the interval (1-k)T it reduces by $-(V_o - 2V_1)$.Thus

$$V_2 = \frac{2-k}{1-k}V_1 = \left(\frac{2-k}{1-k}\right)^2 V_{in} \qquad (6)$$

$$V_{L2} = \frac{k}{1-k}V_1 \qquad (7)$$

Finally output voltage

$$V_o = V_1 + V_{L2} + V_2 = \left(\frac{2-k}{1-k}\right)\left(\frac{3-k}{1-k}\right)V_{in} \qquad (8)$$

Gain

$$G = \frac{V_o}{V_{in}} = \left(\frac{2-k}{1-k}\right)\left(\frac{3-k}{1-k}\right) \qquad (9)$$

C. Triple lift Additional Circuit

In this DEC circuit is added to form the triple lift additional circuit [7] as shown in the figure 4.

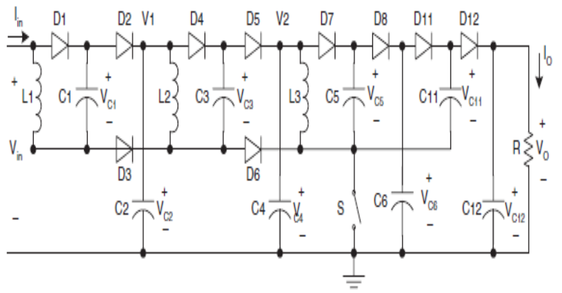

Figure 4(a)

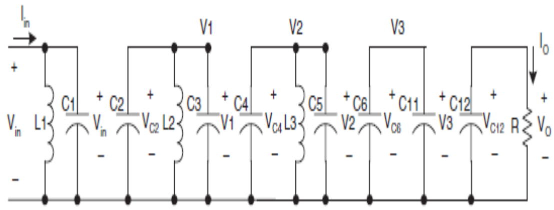

Figure 4(b)

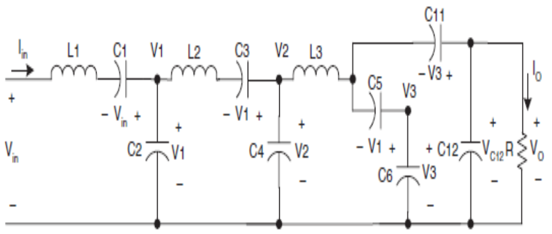

Figure 4(c)

C_1 is charged to the voltage V_{in} and the C_2 holds the voltage

$$V_1 = \frac{2-k}{1-k} V_{in} \qquad (10)$$

And C_4 holds the voltage as

$$V_2 = \frac{2-k}{1-k} V_1 = \left(\frac{2-k}{1-k}\right)^2 V_{in} \qquad (11)$$

The C_5 is excited to V_2 and the capacitors C_6 and C_{11} excited upto V_3 and the current passing through inductor rises during the turn on time kt with the voltage V_2 and diminishes during (1-k)T, thus

$$V_3 = \frac{2-k}{1-k} V_2 = \left(\frac{2-k}{1-k}\right)^2 V_1 = \left(\frac{2-k}{1-k}\right)^3 V_{in} \qquad (12)$$

$$V_{L3} = \frac{k}{1-k} V_2 \quad (13)$$

The output voltage is

$$V_o = V_2 + V_{L3} + V_3 = \left(\frac{2-k}{1-k}\right)\left(\frac{3-k}{1-k}\right) V_{in} \qquad (13)$$

Gain

$$G = \frac{V_o}{V_{in}} = \left(\frac{2-k}{1-k}\right)^2 \left(\frac{3-k}{1-k}\right) \qquad (14)$$

IV. DESIGN OF PI CONTROLLER

In the feedback system the main role of the controller is to obtain the regulated output which is achieved by comparing the variable measured by the process and the compare it with the reference value and then controller will take the necessary action .The error signal is calculated by comparing the set point value and the measured value. A proportional constant gain and the gain calculated by iterating the error is fed to the process[8] . The control signals

$$. u_c = K_p e + K_i \int_0^t e dt \qquad (15)$$

The proportional gain fastens the response gives the stable of the controlled output and but the offset is always present. Integral controller eradicates the offset . So proportional plus integral controller is one of the finest option.

Now there again exists the issue of calculating the optimal values of Kp and Ki to obtain the desired response. The controller will give the best performance if it is tuned optimally. Tuning methods like Ziegler –Nicholas tuning are available. In this paper the controller is optimized using the particle swarm optimization technique.

V. PARTICLE SWARM OPTIMIZATION

There is the need to optimize the parameters of the PI controller in order to get the optimum results[9]. There are various Optimization techniques available and PSO is applied for the optimization of the controller in this research .PSO belongs to the class of optimization call met metaheuristic The technique was developed in 1995 by Dr Eberhart and Dr. Kennedy. The motivation behind this was the social deeds of the flocking birds .PSO is easy to implement and has less number of variables and can be applied to the controllers like neuro and fuzzy for optimization of their parameters. The technique is explained by analyzing the behavior of birds that are in search of food. The entire flock of birds move seeing each other to the desired location. Each bird in the area is represented as particle.[10] The fitness function which has to be optimized is used to give the fitness values to each particle and velocity function at which the particles flutter in the course of the defined area by following the optimum particles.

PSO is basically collection of particles. Among which two best values are found in each iteration. the first best values is called "pbest" which is basically the best value found . and the second best is the "gbest" which is basically the globally best value.The first is the best solution (fitness) it has accomplished up until now. [11].

Following are the equations for calculating best values of velocity coefficient and position coefficient and are updated accordingly:

$$V_i^{k+1} = wV_i^k + C_1 * rand(pbest_i - S_i^k) + C_2 rand(gbest_i - S_i^k)$$
(16)

$$X_i^{k+1} = X_i^k + V_i^{k+1} \qquad (17)$$

Vi is the velocity coefficient at k+1 iteration of ith particle.

Xi being ith particle position coefficient at k+1 iteration.

W being function of weights.

C1 is one of acceleration constant and is also stands for cognitive learning rate.

C2 is also acceleration constant and represents social learning rate.

rand correspond to the random function with value between 0 to1.

pbest represent the entity best value and gbest as global best value.

The flow chart is shown below

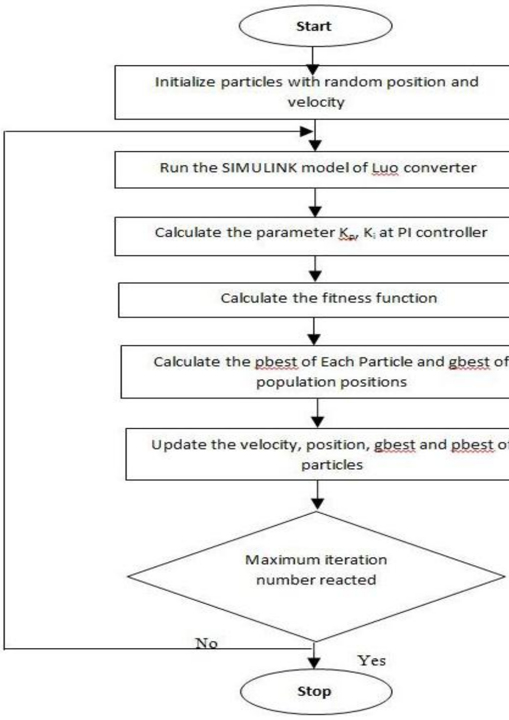

Figure 5. Flowchart of PSO

For adjusting the velocity of particles weighing function is being used and hence use to balance between the global and local search. For global search large inertia weight is applied by using PSO algorithm and it is eventually reduced for the local search at the verge of the completion of the execution process.

Following is the expression for the calculation of weighing function

$$W = W_{mx} - \frac{(W_{mx} - W_{mn}).itr}{itr_{mx}} \qquad (18)$$

Where W_{mx} and W_{mn} are referred as final and initial weights,itr is referred as current iteration instant and itr_{mx} is the utmost iterations.

Below is the proposed fitness function for the optimization of PI controller parameters.

$$F(s) = W_{mx}\left(M_p + ISE + IAE\right) + W_{mn}(T_R + T_s) \qquad (19)$$

Performance Indices are calculated using (ISE) and (IAE).

VI. SIMULATION & RESULTS

The Additional series converters are simulated in the PSIM environment . the input voltage Vin = 20 V, L1 =L2=L3 =10mH, C1=C2=C3=C11=C12=2uF.The PI controller is used for the closed loop control of the converters[12] . The values of P & I are the optimized values and are calculated using the particle swarm optimization. Each of the converter is simulated for by applying the simulation control of 5 sec. resistance R = 30 K ohms and the switching frequency 10 KHz and duty ratio 50 % . Kp= 0.4798, Ki = 33.8203 are the optimised values of PI[a]. All the simulations are carried in PSIM and the optimal of the PI controllers are calculated in MATLAB using the particle swarm optimisation technique[13].

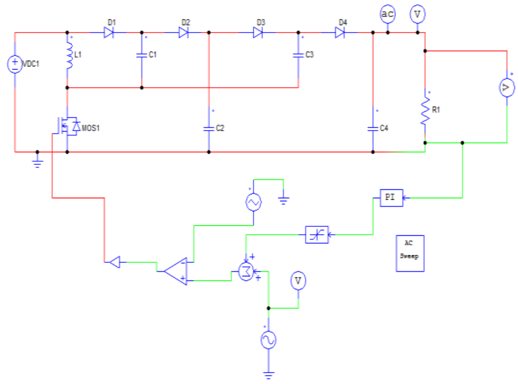

Fig:6(a)

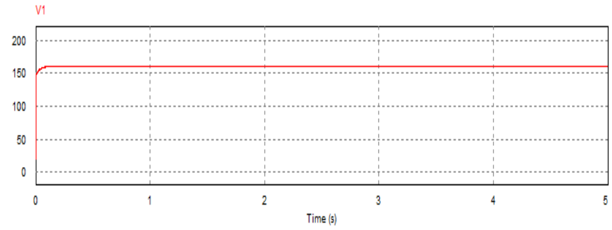

Fig 6(b)

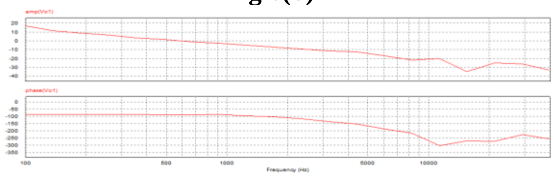

Fig 6(c)

Figure 6 (a) Simulation circuit of Elementary additional series converter,6(b) Output voltage of Elementary converter 6(c) Stability analysis of elementary additional series with PM=-87,GM=-16.1

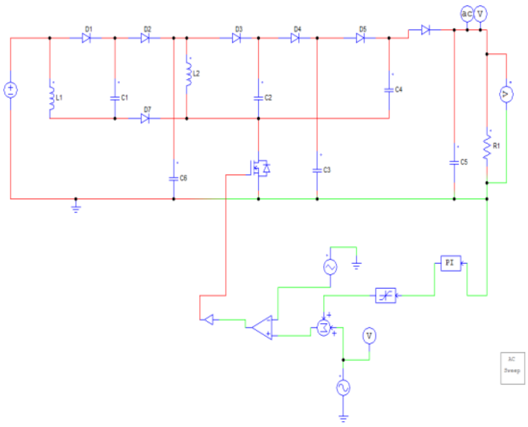

Fig 7(a)

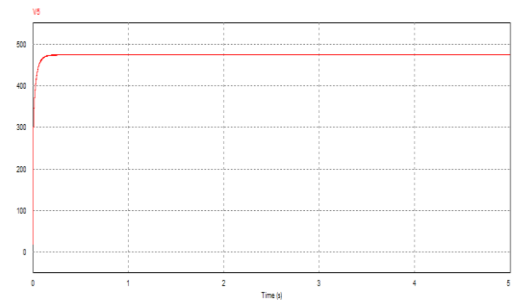

Fig 7(b)

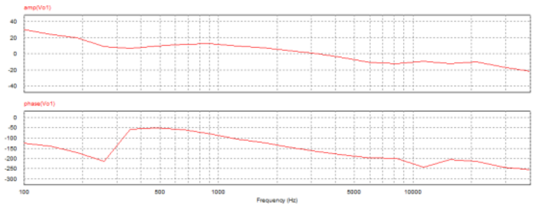

Fig 7(c)

Figure 7 (a) Simulation circuit of Re-Lift Additional series converter,7(b) Output voltage of Re-Lift Additional converter 7(c) Stability analysis of Re-Lift Additional series with PM =-15.6, GM = -4.3

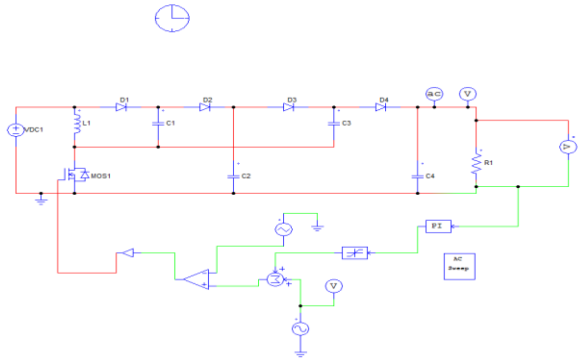

Fig 8(a)

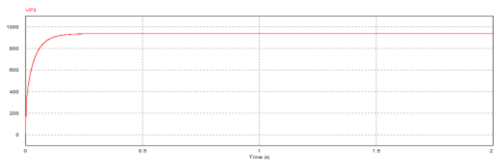

Figure 8(b)

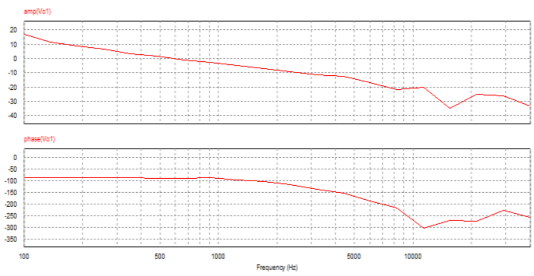

Fig 8(c)

Figure 8(a) Simulation circuit of Triple Lift Additional series converter,8(b) Output voltage of Triple Lift Additional converter 8(c) Stability analysis of Triple Lift Additional series PM =-129.7,GM =2.5

VII. CONCLUSION

The performance of the DC –DC boost converter is effected by the effect of the parasitic element which produces ripples in the output voltage. In order to eradicate this effect and to raise the output voltage level to an effective amount the Luo converter topology are beneficial. There are various categories in which the Luo converters are divided. Positive output Luo converter series converter are discussed in the work. These are further classified into different series . Additional series luo converter is simulated . PI controller is used to control the converter in its closed loop mode . The performance of the converter is optimized by using the optimized values of proportional and Integral controller with the help of particle swarm optimization technique.

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