A COMPARISON BETWEEN OPEN LOOP AND CLOSED LOOP OPERATION OF HIGH GAIN QUASI-Z SOURCE DC-DC CONVERTER

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Abstract: This paper presents examination between open loop and closed loop control for High gain quasi-z source DC-DC converter. This converter utilizes a hybrid switched capacitors switched-inductor method in order to achieve high voltage gains. Moreover, so as to get the controlled output voltage from the DC-DC converter under fluctuating input conditions, it is required to regulate the output voltage which can be obtained by using closed loop control. Closed loop control technique is crucial in power converters to meet the desired load necessities. PI controller is one among the existing control technique. This technique has a single loop arrangement with proportional and integral gains in the forward path. The utilization of PI controller enhances system dynamic response and reduces undesirable peak overshoot, undershoots and also reduces the settling time. Open loop and closed loop control of the proposed High step up DC- DC converter is analyzed and simulated for R load using MATLAB Simulink .

***IndexTerms* - Quasi-Z Source Dc-Dc Converter, Open Loop, Closed Loop, Pi Controller.**

I. INTRODUCTION

In the course of the most recent couple of decade improvement of conventional energy resources like Photovoltaic cell, fuel cell and so forth is high. Level of improvement is expanding step by step [1]. Improvement of conventional energy resources impacts the utilization of DC-DC converter. Fundamental work of DC-DC converter is to change over a dc voltage to another dc voltage level, frequently giving a managed yield.

These days high voltage DC-DC converters are utilized in numerous applications, for example, battery backup system in ups, high intensity discharge lamp ballasts for automobile headlamps, traction system and in medical equipments [2]. In heavy vehicles, for example, utility trucks, long haul trucks and electric buses, vehicle batteries at 12V, 24V or 48V are utilized. They are used to provide power to feed loads such as pumps, air conditioner compressor, power tools, pipe fusion, welding and fans, and so on. Every one of these loads commonly have a 120V or 240V AC voltage interface and their power levels run from hundreds of watts to a few kW, sometimes may achieve 20 kW. Such applications require a high step up DC-DC converter to raise the low battery voltage to 400V DC for DC-AC transformation and capable of working at an extremely high input current (> 200A).It is beyond the realm of imagination to expect to give that much of high voltage by conventional DC-DC converter; multistage fell associated converters give high voltage however they have significant issues, for example, higher switching losses and diode drop, higher duty cycle operation causes savvier reverse recovery issue and high EMI occurrence. As the number of elements increases in circuit overall efficiency of the converter decreases.

The fundamental issue with task of DC-DC converter is unregulated power supply, which leads to improper functioning of DC – DC converters [2]-[5]. There are various analogue and digital control methods used for dc-dc converters and some have been adopted by industry voltage-mode and current-mode control methods. The DC-DC converter inputs are commonly unregulated dc voltage input and required outputs should be a consistent or fixed voltage. Utilization of a voltage controller is that it should maintains a constant or fixed output voltage irrespective of variation in load current or input voltage. Different sorts of voltage controllers with variety of control plans are utilized to upgrade the efficiency of DC-DC converters.

In this paper, the closed loop control for high gain quasi-z source DC-DC converter is implemented. In order to obtain the controlled output voltage from the DC-DC converter under varying input conditions, it is required to regulate the output voltage which can be obtained using closed loop control. Here PI Controller is employed to control output voltage by controlling the input pulse width of active switch in transient as well as steady stage of the converter [6]. The closed loop control of the high gain quasi-z source DC-DC converter is analyzed and simulated for R load using MATLAB Simulink and the results are compared with open loop control system.

II. PRINCIPLE OF OPERATION AND STEADY STATE ANALYSIS

2.1. Converter Configuration

The structure of the proposed high gain QZS dc–dc converter is appeared in Fig 1. Compare to basic QZS converter [7] this converter consisting of C3, C 4, C 5, and C6 as switched capacitors. Switching of the capacitors is done in offline using the diode D2, D3, and D4. The inductor L3 is additionally utilized as the switched inductor in order to increase the voltage boost capability.

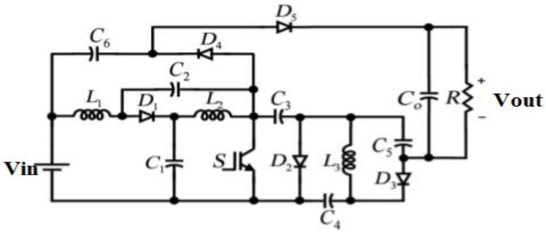

Fig 1: high gain quasi-z source dc-dc converter

2.2. Operation principle

There are four modes of operation under steady state operation of the high gain quasi-z source DC-DC converter.

2.2.1 Mode I

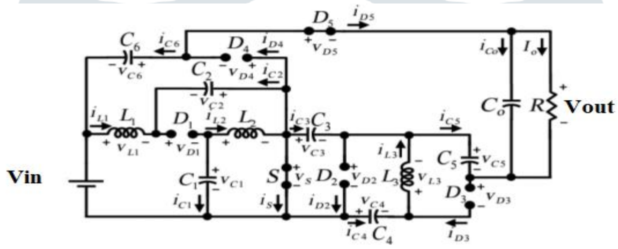

Fig 2: mode 1

This mode starts as the switch turns ON. Fig 2 shows the equivalent circuit diagram of mode 1.In this mode, inductor L1 and L2 are magnetize by capacitor C2 and C1 through the way given by the switch. Capacitor C3 magnetizes the inductor L3, charges C4, and the load. Additionally, considering the conduction of D5, the energy of the load will be given by the input voltage source, and C3, C5, and C6. Hence, the current takes path through L1, L2, and L3 and the voltage across C4 gradually increases and they get charged. While, the voltages across C1, C2, C3, C5 and C6 decreases and they get discharged. This mode will end as the switch turns off.
Considering the ON/OFF circumstances of the switching device, by applying Kirchhoff's Voltage Law (KVL) to the circuit, the following relationships can be written for the first operation mode

$$V_{L1}= V_{in}+ V_{C3} \quad (1)$$

$$V_{L2}= V_{Out} + V_{C2} - V_{C3}- V_{C5}- V_{C6} \quad (2)$$

$$V_{L3}= V_{C3} -V_{C4} \quad (3)$$

2.2.2 Mode II

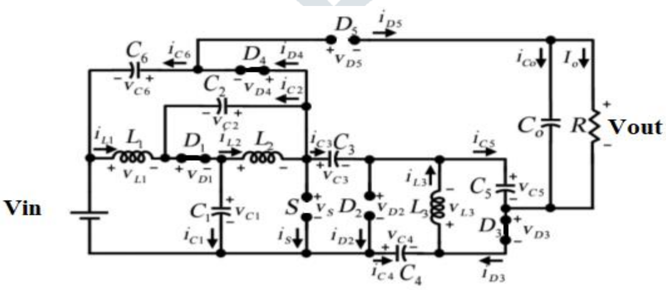

Fig 3: mode II

Fig 3 shows the equivalent circuit diagram of mode II, as the switch turns OFF, the second mode of operation starts. In this mode, D1, D3, and D4 are forward biased, while, D2 and D5 are reverse biased, inductors L1 and L2 charge the capacitors C1,C2, C3 and also C6 through the way given by D4. The capacitor C5 is also charged by L3 and C4.Therefore, the voltages across C1, C 2, C3, C5, and C6 gradually increases and they get charged, while, the voltage crosswise over C4 and the current flows through L1, L2, and L3 decreases and they get discharged.
Considering the ON/OFF circumstances of the switching device, by applying Kirchhoff's Voltage Law (KVL) to the circuit, the following relationships can be written for the second operation mode

$$V_{L1}= V_{in}- V_{C1} \quad (4)$$

$$V_{L1}= V_{C2} - V_{C6} \quad (5)$$

$$V_{L2}= V_{C1} - V_{C3}+V_{C4}- V_{C5} \quad (6)$$

$$V_{L2}= - V_{C2} \quad (7)$$

$$V_{L3}= - V_{in} +V_{C3} -V_{C4} -V_{C6} \quad (8)$$

2.2.3 Mode III

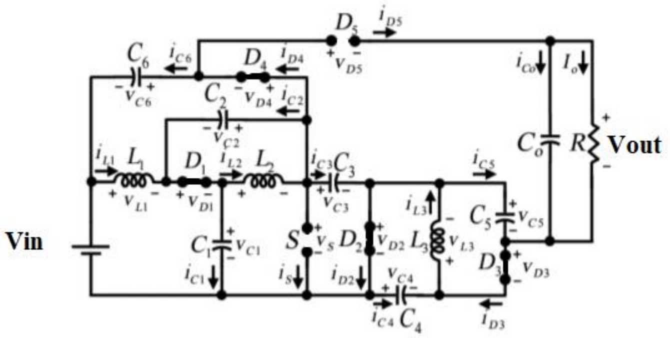

Fig 4: mode III

Fig 4 shows the equivalent circuit diagram of mode III.As it was referenced, in mode II, the voltage across C4 diminishes while the voltage across C5 increases. As V_{C4} reaches to V_{C5}, the voltage across D2 gets positive, and therefore D2 gets forward biased and ready to conduct. As D2 conducts, the third mode of operation begins. Hence, in this mode, the switch is still OFF, D1, D3, and D4 are forward biased, and D2 and D5 are reverse biased. Inductor L1 and L2 charge C3 and C5 and also C6 through the path provided by D4. considering the conduction of D2, the capacitors C4 and C5 are associated in parallel and get charged through inductor L3.Therefore,the voltages across C1, C2, C3, C4, C5,and C6 decreased and they get discharged, while, the current going through L1, L2, and L3 increase and they get charged.
Considering the ON/OFF circumstances of the switching device, by applying Kirchhoff's Voltage Law (KVL) to the circuit, following relationship can be written for this mode.

$$V_{L3}= -V_{C4} \quad (9)$$

III. Closed Loop Control Of High Gain Quasi-Z Source DC-DC Converter

In order to obtain the controlled output voltage from the DC-DC converter under varying input conditions, it is required to manage the output voltage which can be obtained using closed loop control [8]. This can be accomplished with the help of negative feedback which is called as closed loop technique. For PWM dc-dc converters, the control of the output voltage can be done in a closed-loop style utilizing two normal closed-loop control techniques to be specific,

- The voltage-mode control.
- The current-mode control.

3.1 Voltage-Mode Control

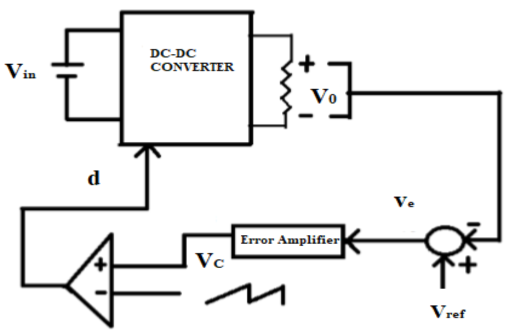

Fig 5: voltage-mode control

The block diagram of Voltage mode control is illustrated in Fig 5. This technique helps in sampling the converter output voltage and compared with the reference voltage which results in error voltage. The error voltage is then fed to the error amplifier which produces a controlled voltage which is then compared with a constant-amplitude saw tooth waveform. The main switches of the converter are provided with the PWM signals produced by the comparator, with adjusted duty cycle for stabling the output voltage to the desired level

The Error amplifier shown in Fig 6 reacts fast to changes in the converter output voltage. Thus, the voltage control loop provides good load regulation. To alleviate this line regulation problem, the voltage control loop scheme is sometimes augmented by a so called voltage-feed forward path. The feed forward path affects directly the PWM duty ratio according to variations in the input voltage.

3.2 PI Controller

Controller generally tries to keep the required variable to set point or to the estimation of the reference point. The feedback control system generally does this by looking the error signal, which is the difference of the output and the reference. Based on generated error controller attempts to set signal to actuator.

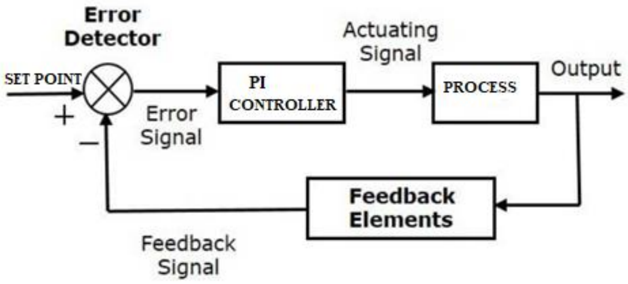

Fig 6 : Block Diagram of PI Controller

Fig 6 demonstrates the block diagram of PI Controller. in this set point is the reference sign and process is the plant which should be control, for this situation the high gain quasi-z source DC-DC converter is the plant. The equation of the control signal u(t) for PI controller is given by

$$u(t) = K_p e(t) + K_i \int_0^t e(t)dt + u(0)$$

u(0) = initial value of the output at t = 0.

3.3 Controller design

Three common objectives for a control design are:

•To accomplish least (or zero) static error (that is, when in steady state the output of the controller should equal the reference input). This is accomplished if the integral (of the error) block is present in unitary feedback architecture

•To hold the overshoot under a specific rate (0%, 5% or 10% are normal qualities) of the amplitude of a step applied at the reference input; this implies the system output offers a "small bouncing" reaction to changes of the input values

•To ensure that the rising time of the yield is underneath a specific cutoff (that is, we want the system overcome a certain minimum of speed when reacting to a step variation at the input).

The various procedures of controller tuning, known as Ziegler-Nichols strategy have been adopted in this paper. It is to be recalled that the prescribed settings are empirical in nature, and obtained from extensive experimentation with number of different processes; there is no theoretical basis behind these choices [9]. Accordingly, a superior blend of the P, I esteems may dependably be discovered, that will give less oscillation and better settling time. In any case, with no from the earlier information of the framework, it is constantly fitting to play out the experimentation and select the controller settings, obtained from Ziegler-Nichols strategy. But there is always scope for improving the performance of the controller by fine-tuning. So, Ziegler Nichols method provides initial settings that will give satisfactory, result, but it is always advisable to fine-tune the controller further for the particular process and better performance is expected to be achieved. From the Ziegler-Nichols tuning method Kp and Ki values are calculated, values found be Kp=0.58 and Ki=32

IV. SIMULATION RESULTS

The analysis of the open loop and closed loop control of high gain quasi-z source dc-dc converter is presented in this paper through simulation. The circuit components are connected in the Simulink model of the high gain quasi-z source DC-DC converter with the parameters mentioned in table I

Table I: Parameters used for simulation

Parameters	Values
Input Voltage	24V
Output Voltage	364V
Switching Frequency	42kHz
Capacitors	$C_1$and C_2 = 330uF, C_3, C_4 ,C_5, C_6 and C_o = 100uF
Inductors	L_1, L_2 and L_3 = 3mH
Load resistance	500ohm

4.1 Open loop System

The MATLAB simulink model of High gain Quasi-Z-source DC-DC Converter under open loop condition is shown in Fig 7. The design parameters are used as specified in the table 1.

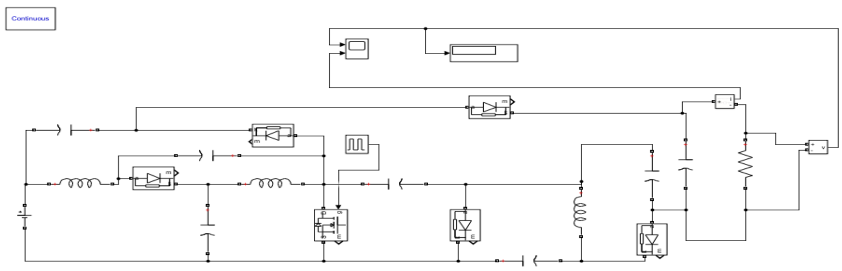

Fig 7: The simulation circuit of open loop system.

The similation results for Quasi-Z-source DC-DC converter under open loop presented in this section. The output voltage and currernt waveform results are shown in Fig 8.

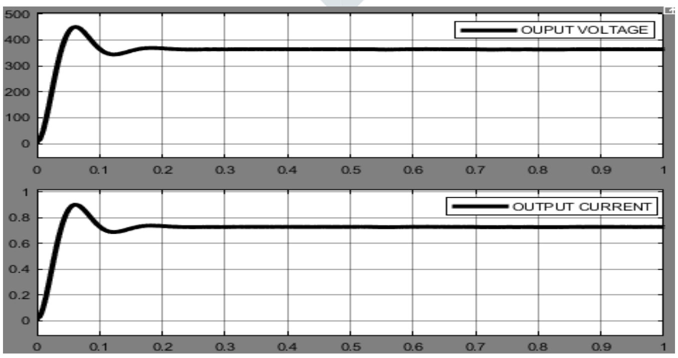

Fig 8: Output voltage and Output current waveform of the converter with open loop system

From Fig. 8, it is evident that, the output voltage of magnitude 364v and the output current of magnitude 0.69A is obtained, which is having steady state error. Initially the overshoot and undershoot occurred, the percentage of overshoot, undershoot, rise time and settling time is tabulated as below.

Table II: step response parameters attained in open loop

Rise Time	Overshoot %	Undershoot %	Settling time
0.025s	25	4.664	0.268s

4.2 Closed loop System

The simılation results for Quasi-Z-source DC-DC converter under closed loop form with PI controller are presented in this section. Kp and Ki values are calculated, values found be Kp=0.58 and Ki=32

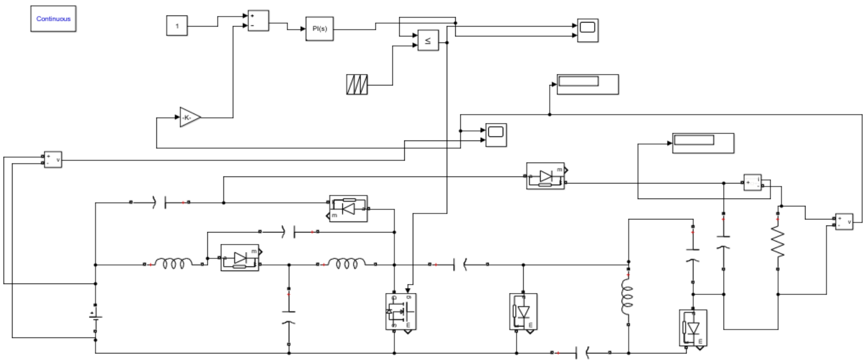

Fig 9: The simulation circuit of Closed loop system.

The MATLAB simulink model of Quasi-Z-source DC-DC Converter under closed loop condition is shown in Fig 9.The output voltage and currernt waveform results are shown in Fig. 10.

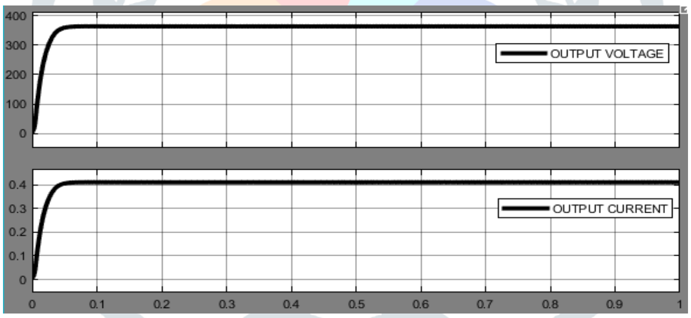

Fig 10: Output voltage and output current waveform of the proposed IBC with Closed loop system

The Fig 10.depicts output voltage and output current waveform with a steady state and without overshoot as compared to the converter in open loop. The output voltage of the converter with controller is almost 365V; it's settling time is around 0.072 seconds. Thus the converter with the controller has reduced settling time and provides the steady state output.

Table III: step response parameters attained in closed loop with PI controller

Rise Time	Overshoot %	Undershoot %	Settling time
0.025s	0.515	0.217	0.072s

V. CONCLUSION

High gain quasi-z source dc-dc converter has been proposed for high voltage conversion. Both open loop and closed loop control system are simulated using MATLAB simulink. The closed control system provides a stable output voltage for any variations in the input voltage. Thus the simulation results shows that the converter with controller reduces the settling time, overshoot and undershoot and provides steady state output and hence improves the converter performance.

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