THE CLOSED LOOP CONTROL OF SOFT SWITCHING ZERO VOLTAGE TRANSITION DC-DC BUCK CONVERETR

[1]Goutami B, [2]Dr. Balaji N

[1]Student, [2]Associate Professor
[1]Department of EEE,
[1]Dayananda Sagar College of Engineering, Bangalore, India

Abstract: DC-DC converters are widely used in many applications to minimize the switching losses and to increase the efficiency the soft switching techniques are used. The analysis and design of closed loop soft switching zero voltage transition dc-dc buck converter have been proposed. The main aim of this project is to reduce voltage and current in zero voltage transition buck converter from photovoltaic panel. A PID controller has been designed for closed loop operation. The simulation studies are done using MATLAB/SIMULINK software.

***IndexTerms* – Zero-voltage transition, switching losses, closed loop.**

I. INTRODUCTION

Now day's industry growth and expansion are tightly related to the progresses that electronics have been experiencing in the last decades. Following this tendency, high performance and small size/weight have become major requirement of electronics equipment. To accomplish these requirements, the power electronic converters must operate at even higher switching-frequency levels. Nevertheless, at those high switching-frequency levels, the switching losses degrade the converter electromagnetic interference (EMI) performance and reduce the converter efficiency. With the increase in losses, the converter heat-sink system inevitably must improve its performance with the enlargement of its volume and size. It brings, as a consequence, a tradeoff between the converter filters and magnetic component size, reduced at the high frequencies, and converter heat-sink size, increased at high-frequency levels. Several soft switching techniques have been introduced in last decades allowing converters to operate at high power and switching frequency levels without penalizing converter efficiency. Among soft switching techniques, zero voltage transition has been used frequently. This technique makes use of low power-rated auxiliary circuit in parallel with the main power path, thus enabling the converter to work as closely as possible to its pulse width-modulation counterpart, with low conduction losses compared to other zero voltage switching techniques.

The DC-DC power converters are extensively utilized in SMPS and are a critical component of DG system, particularly for sustainable energy system based distributed generators. The objective of this project is to design a PV fed buck regulator with feedback control by using classical Proportional plus integral plus derivative controller. PID controller maintains a constant output voltage by varying the input voltage and load. SSA technique is used for getting a linearized model of this power converter and the controller gain parameters are determined by Ziegler-Nichol's tuning method. The mathematical analysis and dynamic model of DC-DC converters can be analyzed by numerical or analytical methods. In numerical methods, various algorithms are used to give quantitative results and in analytical methods, analytical expressions are provided to exhibit the operation and performance of the power converters. The most popular method is the small-signal model analysis, which includes three techniques such as circuit averaging, state-space averaging or PWM switch modeling. In this chapter the linearized model of converter is formed by SSA technique and closed loop control is applied to state space average model of a DC-DC Converter. The PV module consists of number of PV arrays and each PV array consists of many solar cells. The entire PV module depends on solar irradiance and cell temperature. Since PV module has nonlinear characteristics, it is necessary to model and design for PV system applications.

II. CONTROL SYSTEM

A control system is a system that consists of the set of device which controls the other system to obtain the desire results.

2.1 Feature of Control System

Linearity of the system plays a major role in the control system. This is considered as one of the feature of the good control system. One can define the linearity as the, a clear mathematical relation between input and output of the system is called linear control system. If not it is called as the non linear control system.

2.1.1 Requirement of Good Control System

- Accuracy
- Sensitivity
- Noise

- Stability
- Bandwidth
- Speed

2.1.2 Types of Control System

- Open loop control system
- Closed loop control system

2.1.2.1 Open loop control system

The open-loop control system does not monitor or measure the condition of its output signal as there is no feedback. The block diagram of open loop control system is as shown in the fig1, in this the controller output does not depends on the process output.

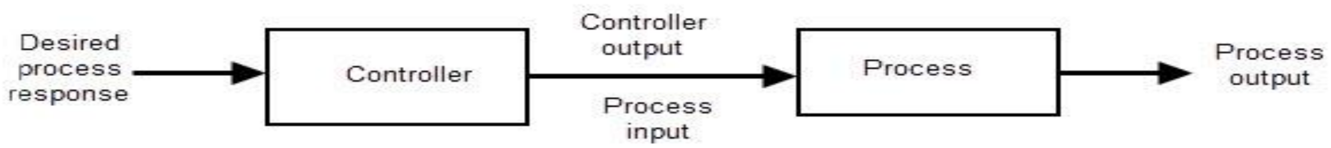

Figure 1: Open loop control system

2.1.2.2 Closed-loop Systems

Closed-loop Systems use feedback where a portion of the output signal is fed back to the input to reduce errors and improve stability. The output depends on the input quantity. The input is adjusted by itself in such a way that the desired output is obtained, even though there is a variation in the input side.

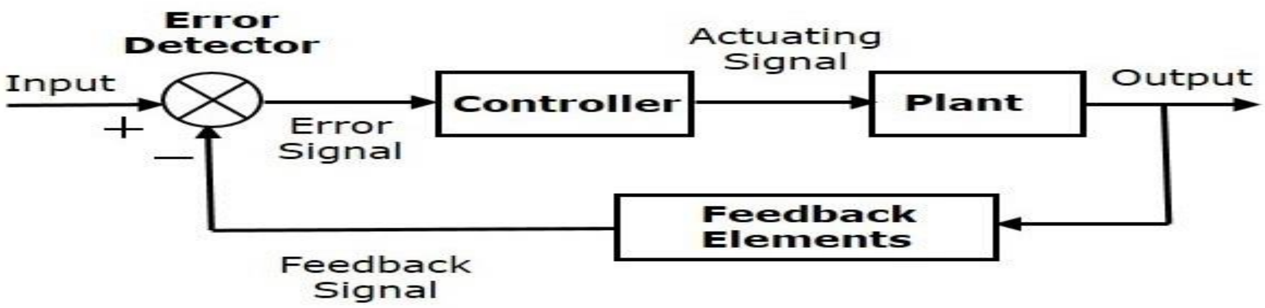

Figure 2: Closed loop control system

2.2 Controllers

The controller is an element that accepts the error in one form and judge the correct action. The output of the controller is applied to the element to be control. The controller brings the output back to its desired set point value from its deviated value. The accuracy of the entire system depends on how the controller handles its own error.
The most important part of the closed loop system, is feedback mechanism. PID controller used in the closed loop control system in the feedback system in the feedback mechanism. The output is delivered based on the Kp,Ki,Kd and the measured error. A well designed feedback system can produce high accurate output.

The main function of the closed loop control technique is reduce error and to increase the stability and sensitivity of the system. In the closed loop control the output voltage is adjusted automatically to the desired value even with the variation in the input quantity.

2.2.1 Properties of the controller

The actual output is sensed by a sensor and converted to a proper feedback signal using a feedback element. The set point value is the reference input and the feedback signal is b(t). The feedback signal is compared with the reference input. The difference between the feedback signal and the set point is called error of the control system.

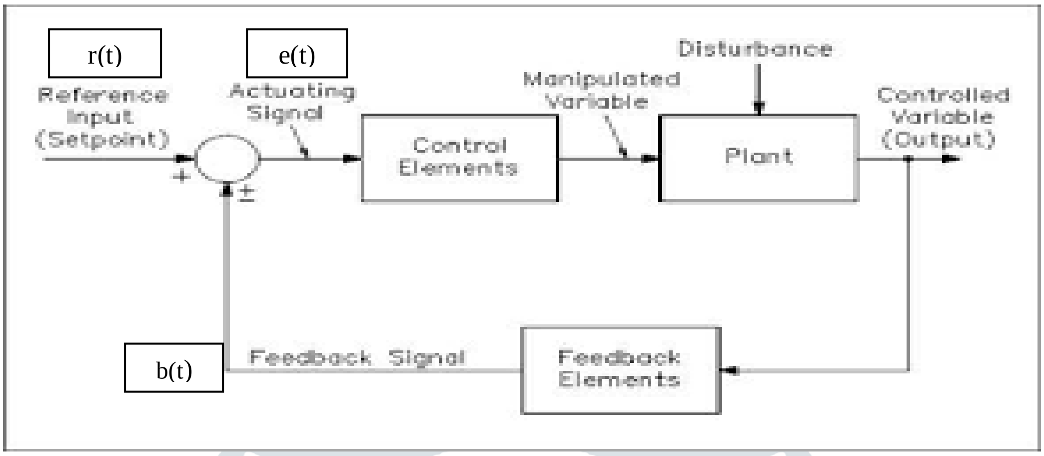

Figure 3: Block diagram of the controller

2.2.2 Composite control modes

- Proportion controller with the integral control mode (PI)
- Proportion controller with the derivative control mode (PD)
- Proportion, integral controller with the derivative control mode (PID)

2.2.3 PID Controller:

A proportional–integral–derivative controller is a control loop feedback mechanism widely used in industrial control systems and a variety of other applications requiring continuously modulate control. A PID controller continuously calculates an error value as the difference between a desired set point (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively), hence the name.

$$u(t) = Kp\, e(t) + Ki \int_0^t e(t^1)dt^1 + Kd\, de(t)/dt$$

Where Kp, Ki and Kd all non-negative, denote the coefficients for the proportional, integral, and derivative terms respectively (sometimes denoted P, I, and D).

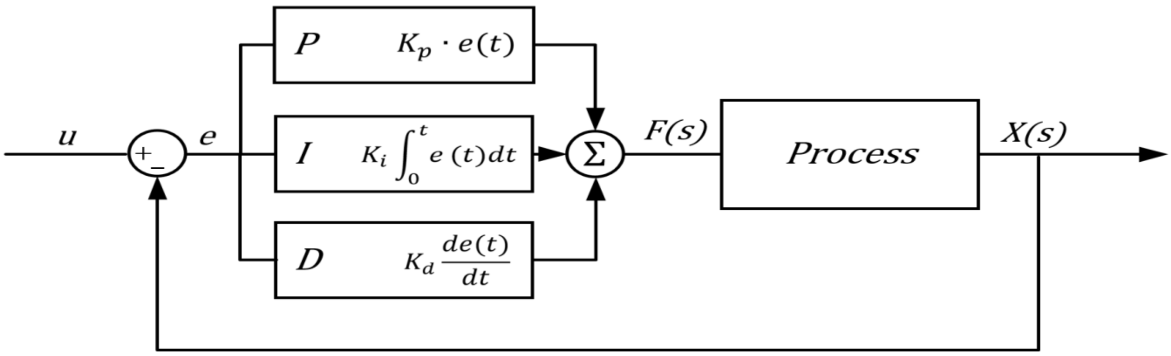

Figure 4: Block diagram of the PID controller

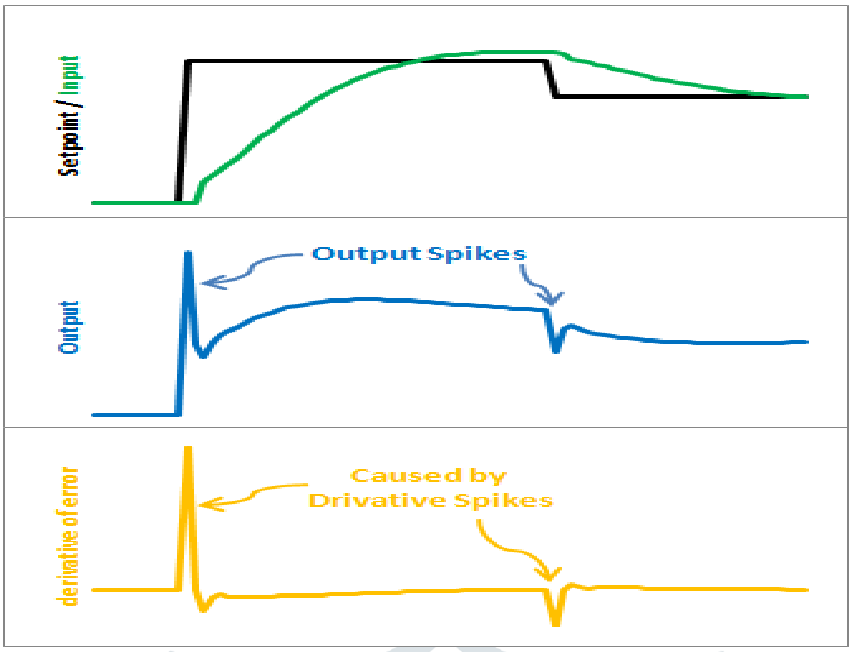

Figure 5: Behavior of the PID controller

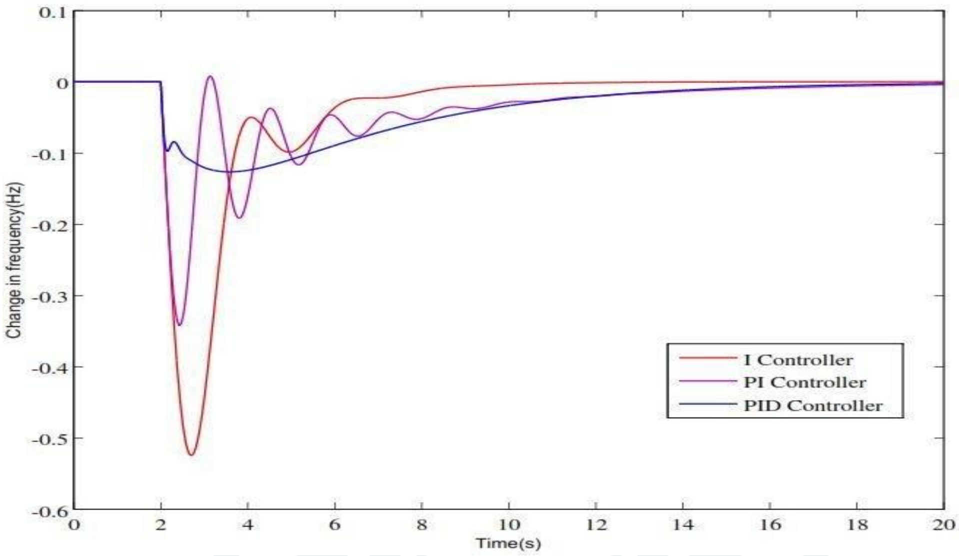

Figure 6: Comparison behavior of PI, I, PID Controller

- PI controller: The aim of using P-D controller is to increase the stability of the system by improving control since it has an ability to predict the future error of the system response. In order to avoid effects of the sudden change in the value of the error signal, the derivative is taken from the output response of the system variable instead of the error signal. Therefore, D mode is designed to be proportional to the change of the output variable to prevent the sudden changes occurring in the control output resulting from sudden changes in the error signal. In addition D directly amplifies process noise therefore D-only control is not used.
- PID controller: P-I-D controller has the optimum control dynamics including zero steady state error, fast response (short rise time), no oscillations and higher stability. The necessity of using a derivative gain component in addition to the PI controller is to eliminate the overshoot and the oscillations occurring in the output response of the system. One of the main advantages of the P-I-D controller is that it can be used with higher order processes including more than single energy storage.
- Integral control is the control mode where the controller output is proportional to the integral of the error with respect to time, i.e. controller output ∞ integral of error with time.

Table 1: Characteristics of P, I, D controllers

	RISE TIME	OVERSHOOTS	SETTLING TIME	STEADY STATE ERROR
Kp	DECREASE	INCREASE	SMALL CHANGE	DECREASE
Ki	DECREASE	INCREASE	INCREASE	ELIMINATE
Kd	INCREASE	DECREASE	DECREASE	NO CHANGE

2.3 Tuning methods of controller

Since PID controllers are widely used in many applications, it is a challenging task to tune the PID controller to achieve the optimum solutions for the Kp, Ki and Kd values. There are many tuning methods, but most common methods are as follows:

- Manual Tuning Method
- Ziegler-Nichols Tuning Method
- Cohen-coon Tuning Method
- PID Tuning Software Method

2.3.1 Ziegler-Nichols Tuning Method: (general procedure to design PID controller)

P-I controllers are used in many applications than the P-I-D controllers. The main logic used for the tuning in this from the neutral heuristic principle. P control gain is verified whether it is positive or negative. To check the steady state error output, the step input is increased manually. This increases the steady state error. Thus we can call the error as positive, if the steady state error decreases, we call error as negative. Then, integral constant and derivative constant are set to zero and only proportional gain constant is increased till it creates a periodic oscillation at the output response. This critical Kp value is to called as the “ultimate gain” (Kc) and the period where the oscillation occurs is named as the (Pc) “ultimate period”.

The tuning of the PI controller with the values of Kc and Pc are doing using the fig 8.

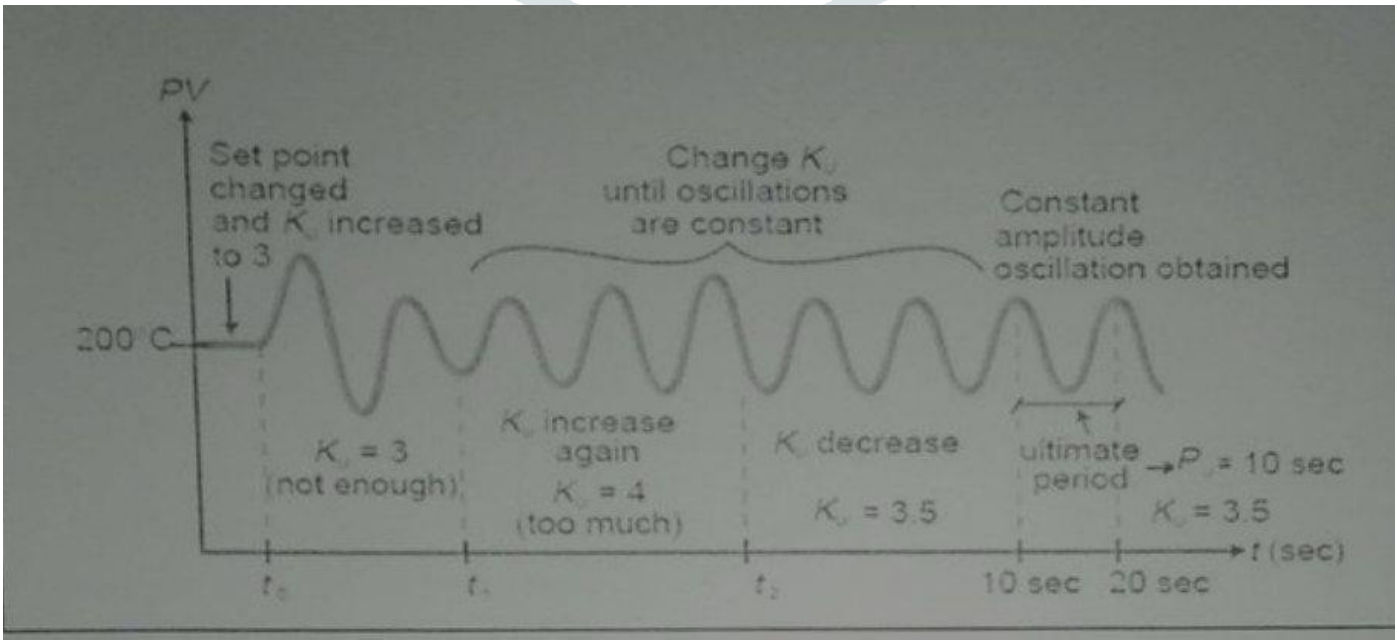

Figure 7: Ziegler-Nichols PID controller Tuning Method

In the present project Ziegler-Nichols Tuning Method has been used.

Ziegler–Nichols method giving K' values
(loop times considered to be constant and equal to dT)

Control Type	Kp	Ki'	Kd'
P	$0.50K_c$	0	0
PI	$0.45K_c$	$1.2K_p dT/P_c$	0
PID	$0.60K_c$	$2K_p dT/P_c$	$K_p P_c/(8dT)$

Figure 8: Ziegler-Nichols PID controller Tuning Method, adjusting Kp, Ki and Kd

III. DESIGN OF THE CLOSED LOOP SOFT SWITCHING ZVT BUCK DC-DC CONVERTER

The objective of this project is to design a PV fed buck regulator with feedback control by using classical Proportional plus integral plus derivative controller. PID controller maintains a constant output voltage by varying the input voltage and load. SSA technique is used for getting a linearized model of this power converter and the controller gain parameters are determined by Ziegler-Nichol‘s tuning method. The analysis and design of closed loop soft switching zero voltage transition dc-dc buck converters have been proposed. The main aim of this project is to reduce voltage and current in zero voltage transition buck converter from photovoltaic panel. The closed loop operation of the ZVT Buck dc-dc converter is as shown in fig 9. Here the output of the converter is taken as the feedback and it is compared with the external dc voltage. This compared signal is given to the controller for the generation of the error signal. This error signal is compared with the PWM signal generated.

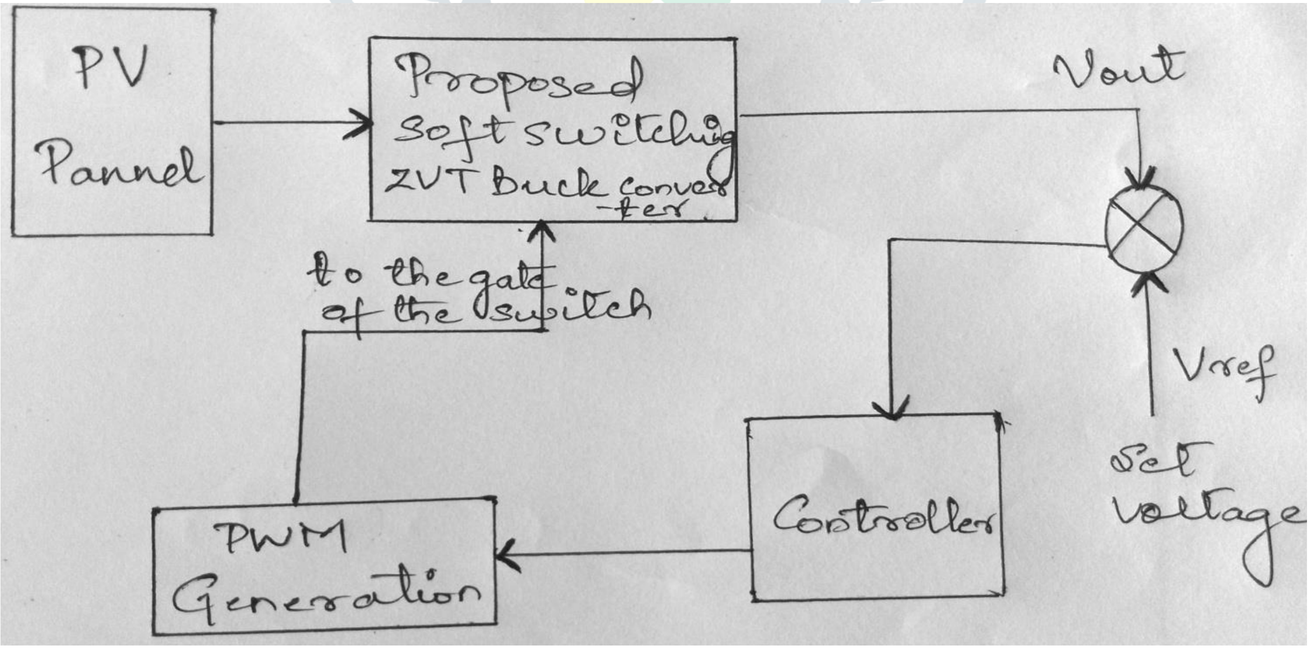

Figure 9: Block diagram of the typical closed loop operation of the ZVT Buck dc-dc converter

VIN = 157; VO = 36
Switching frequency = 12 KHz
R = 100 R0 = 50
C = 3000 µF, C0 = 4700 µF, C1=C2= 0.1 µF
L1 = 90×10^4; L2 = 150mH

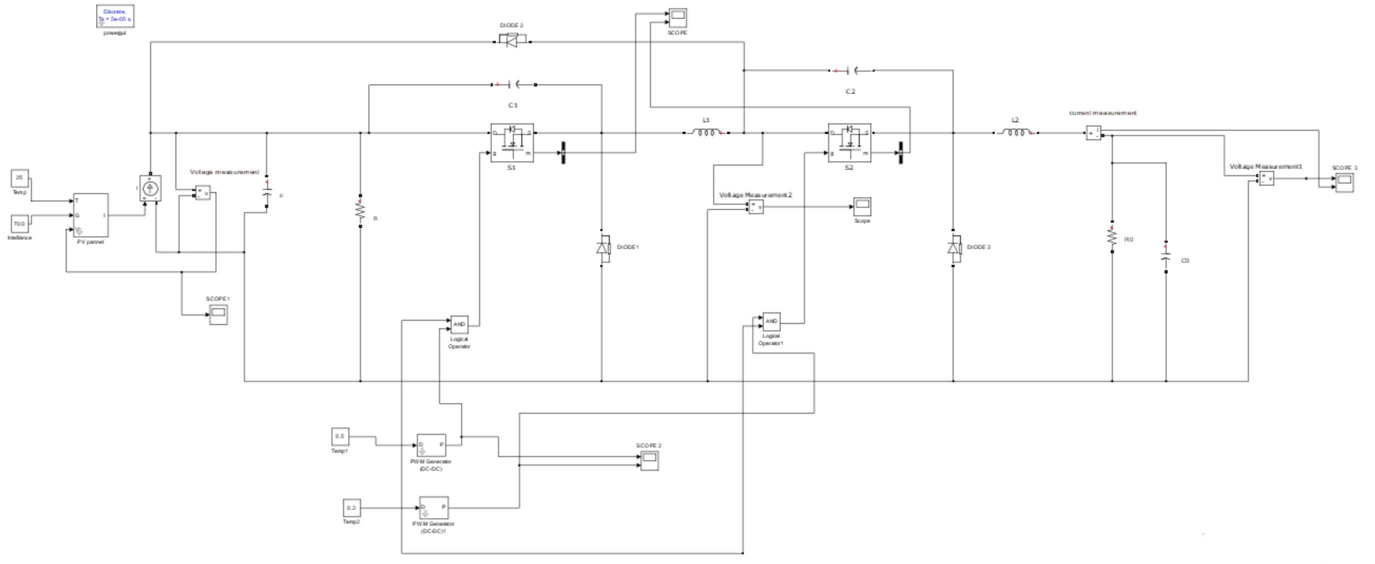

Figure 10: Simulink model of soft switching ZVT buck DC-DC converter in open loop opeartion

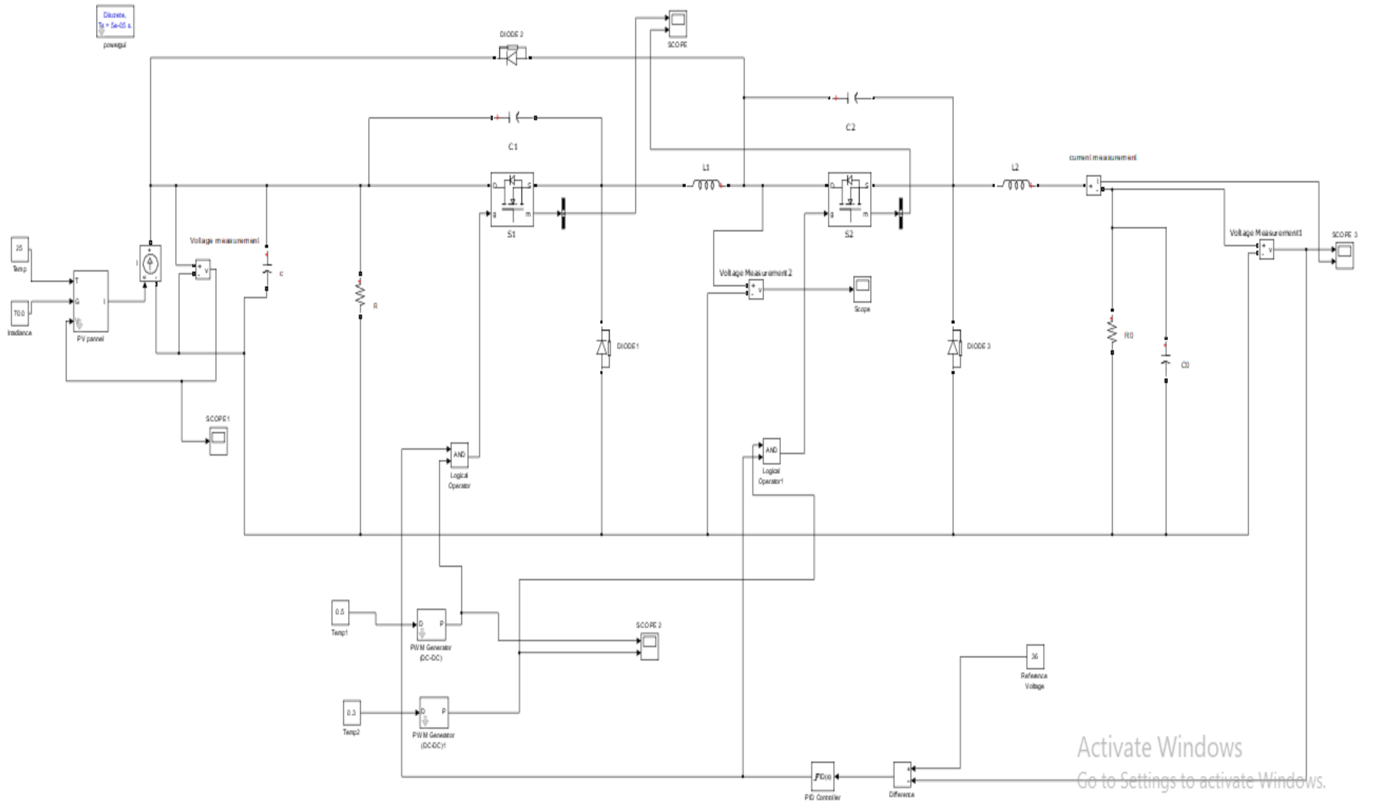

Figure 11: Simulink model of soft switching ZVT buck DC-DC converter in closed loop opeartion

IV. RESULTS AND DISCUSSION

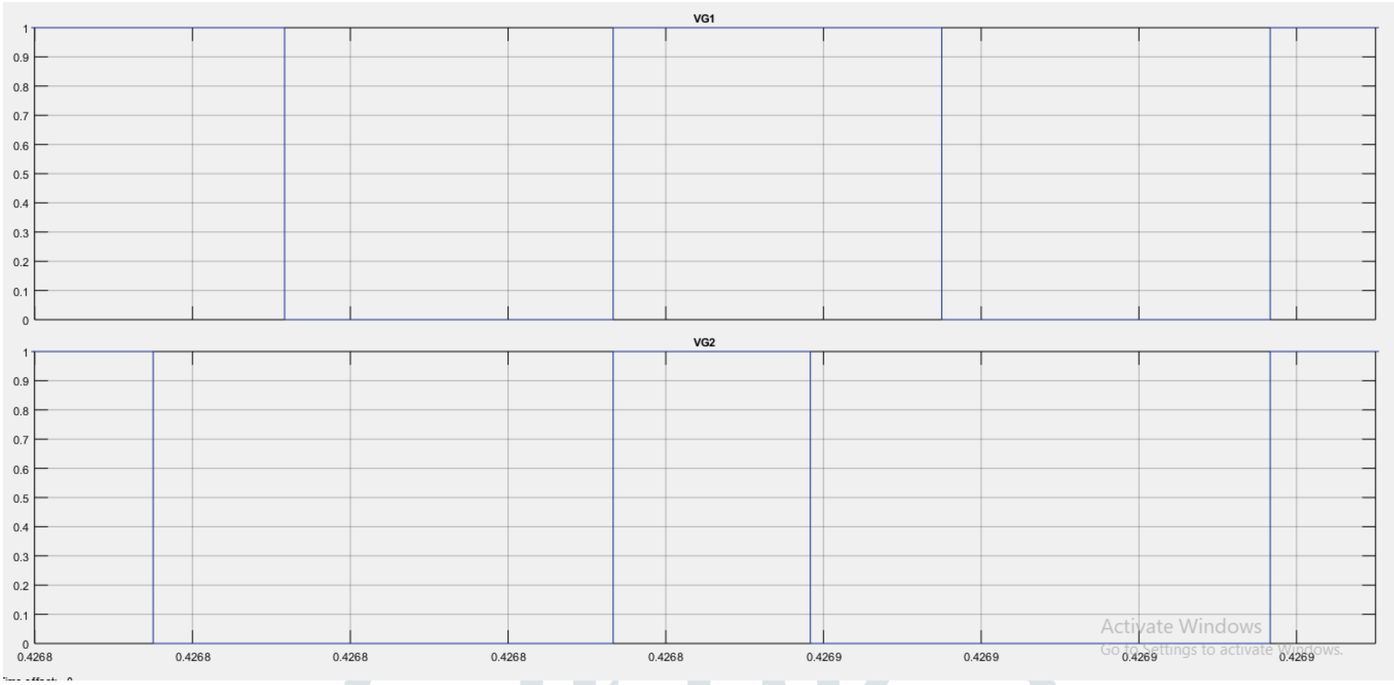

Figure 12: Waveform of gate voltages VG1 and VG2

The above fig.12 depicts the gate voltages waveform of the switches S1 and S2

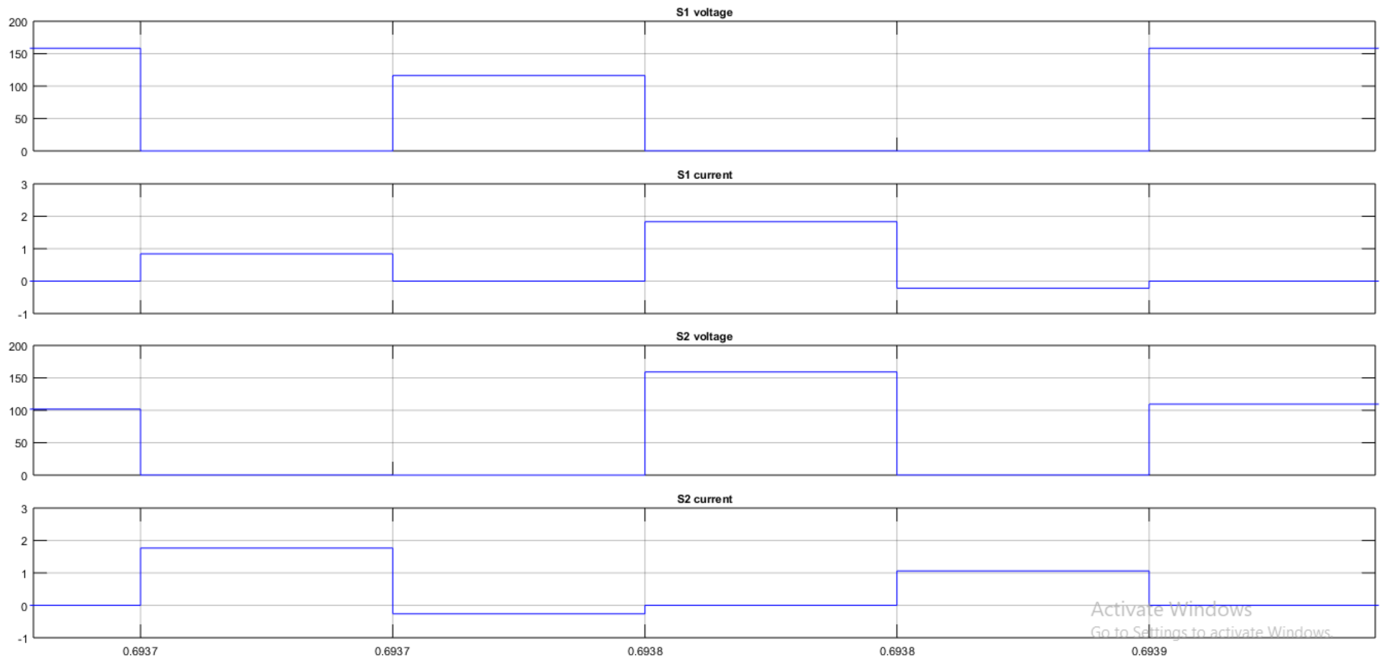

Figure 13: Voltage and Current waveform of S1 and S2

The above fig.13 depicts the voltage and current waveforms of the switches S1 and S2, when S1 has max voltage the current through it is zero and when S1 has zero voltage then current through is minimum and vice versa with S2

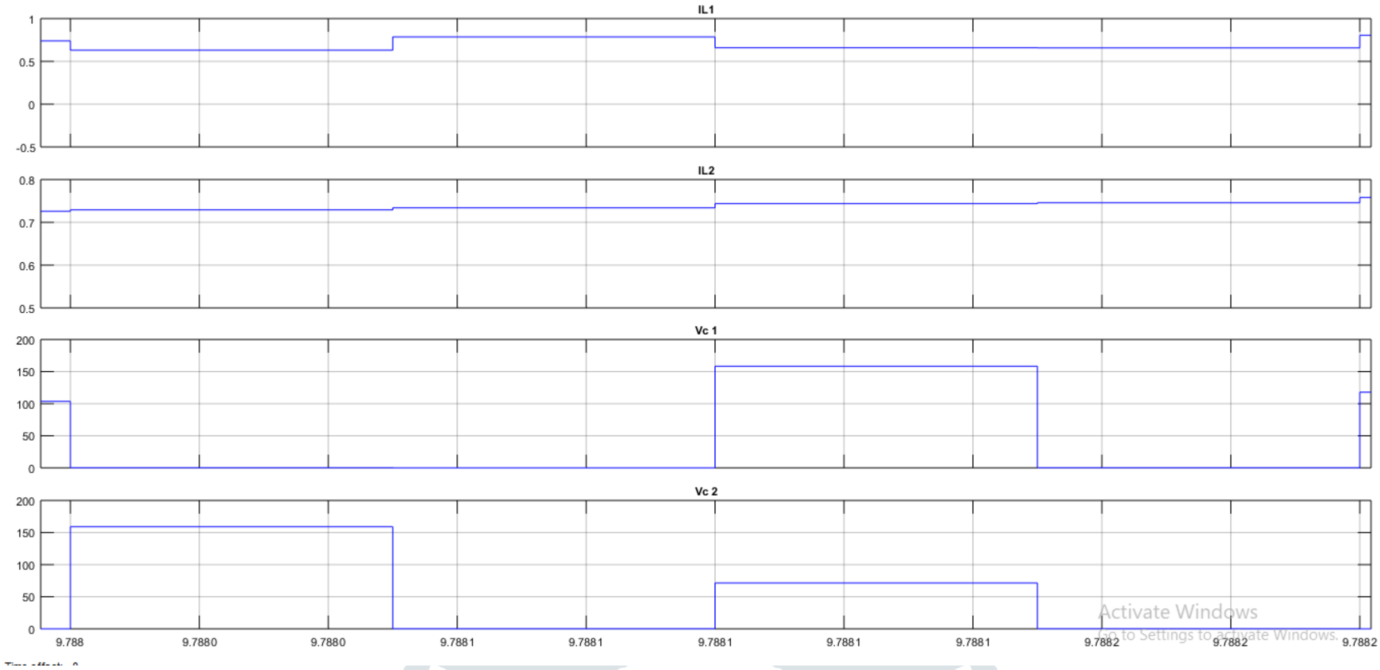

Figure 14: Waveforms of inductor currents IL1, IL2 capacitor voltages of Vc1, Vc2

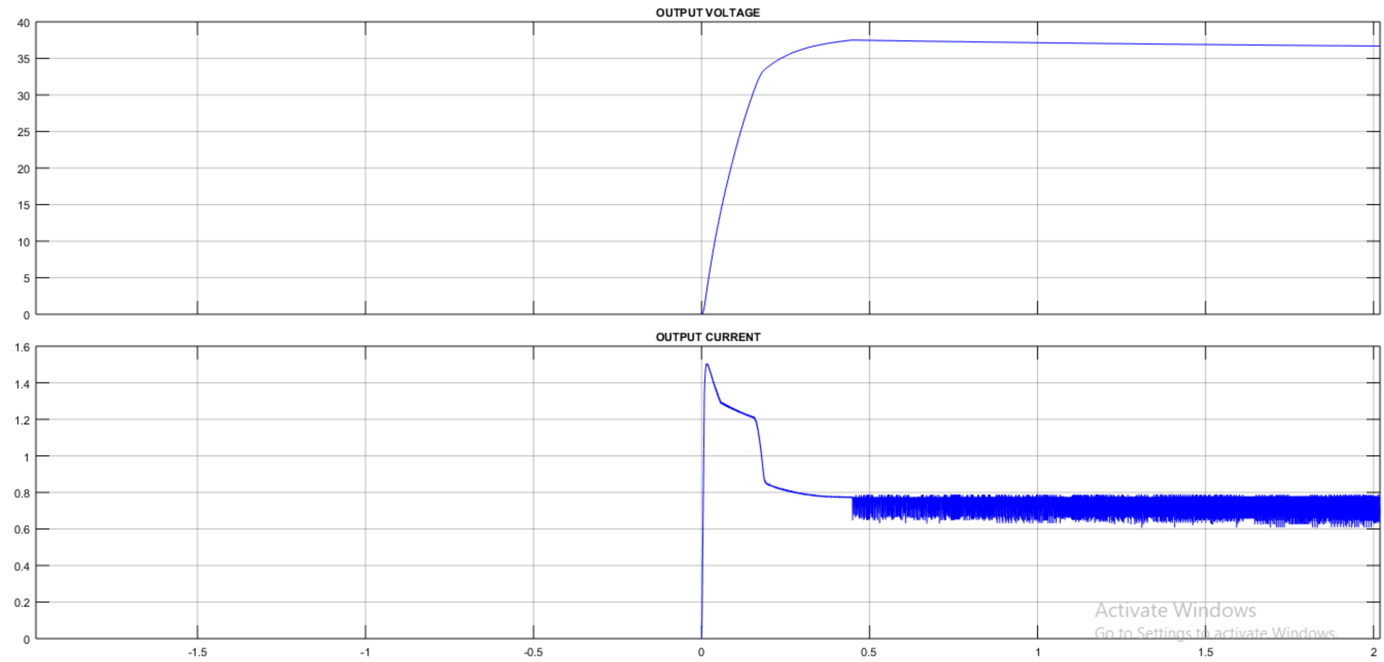

Figure 15: Output voltage and current waveforms

The above fig.15 depicts the output voltage and current ZVT buck converter

V. CONCLUSION

The modeling of a low stress soft switched ZVT Buck DC-DC converter is done. The proposed closed loop control of ZVT buck converter has eliminated large current and voltage stresses which are generally exhibited by the capacitor of resonant converters. The closed loop ZVT buck converter is simulated in MATLAB/SIMULINK software. The auxiliary switch forms a resonant loop, reduces voltage and current on the main switch to zero, which switches before the main switch is switched to the conducting state. The efficiency is of this converter is improved which is higher than ZVS resonant buck converter.

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[3] Photovoltaic Based Zero Voltage Transition DC-DC Buck Converter L. Ashok Kumar1, R.Selvamathi5 1Department of EEE, PSG College of Technology, Coimbatore, India 5AMC Engineering College Bangalore, India V.Indragandhi2, ,D.Elangovan3, G.Arunkumar4 2,3,4School of Electrical Engineering, Vellore Institute of Technology, Vellore-632014 , India