DESIGN OF PID CONTROLLER FOR DC TO DC CONVERTER TO IMPROVE THE VOLTAGE PROFILE

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Abstract— The several practicals and industrial applications of power electronic based cuk converters are used in hybrid electric vehicles, renewable energy system, electronic voltage regulators, etc, to provide required voltage regulation between the input DC and output DC for the better result of all these kind of practical applications , it seeks a quick and stable response from a cuk converter along with regulated DC output magnitude. By using of closed loop PID(proportional cum integral cum derivative) controller we control the converter. By using the PID controller the efficiency of the overall converter depends on how well we tuned our PID controller.

There are so many methods for tuning the PID Controller gain specification and to find the best tuning method is a difficult task. But a method is not generalized for other system it's just best for a given application. Hence for different application there may be different methods of tuning for better result .So, basically this project is performed on MATLAB software where we can tuned the PID controller by several methods and compare all of them and taken out the best result for the cuk converter control application with the help of time domain performance model and frequency domain stability model.

1. INTRODUCTION

This project is specifically used for renewable power source like solar, wind energy system. In this challenge cuk converter is used because Voltage regulation for DC application device is particularly carried out with the assist of DC/DC converter .The cuk converter is used to nullify the voltage variant produces by the variation in the intensity of sun light and wind flow. Hence cuk converter is best of this application. The L-C circuit is used to compensate the ripple content material in output of the device because due to a few ripple element the output reaction of cuk converter isn't pop out as a constant DC.The main characteristic of cuk converter is to changed the enter voltage to the output voltage with contrary polarity. In this undertaking PID controller is used to improve the output voltage of the machine to get the extra solid and correct result however for this the PID tuning is important so In this assignment numerous conventional PID tuning strategies are computed manually and applied to the PID controller of cuk converter to get smooth transient state and low gain values and less settling time.

2. OBJECTIVE OF THIS PROJECT

The main objective of our project is to improve the output volatge profile and minimize the output voltage oscillations of the cuk converter.

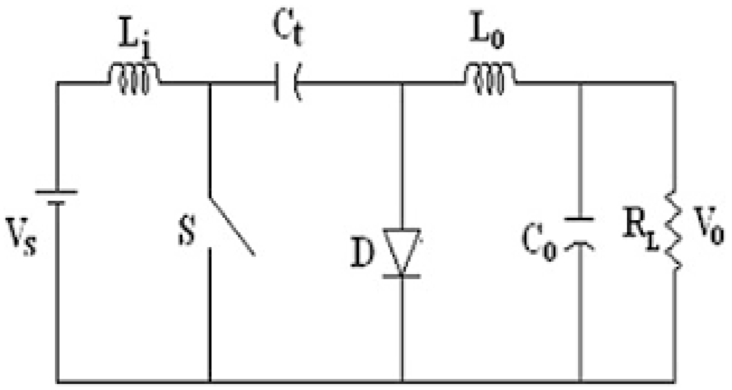
1. As we known for voltage regulation for DC application system the use of DC-DC converter is must.

- **Cuk converter -** The cuk converter is mainly used in DC applications as the main function of this converter is to transform the input voltage to the output voltage with inverse polarity and due to constant input and output current this converter is more useful for these types of applications .In this project we used the PID controller to enhance the output voltage and to get the more stable result from cuk converter.

EXPLANATION OF CUK CONVERTER

Cuk converter changes the magnitude of the output voltage in both the form i.e in higher as well as lower form then the magnitude of input voltage. The main function of cuk converter is to transform the input voltage to the output voltage with inverse polarity.

- In this converter the power from input part to the output part is transferred through the coupling capacitor (Ct) .If we look at figure it shows that the circuit of cuk converter is the mixture of step down converter and step up converter. It consists of four energy storing element i.e two capacitors (Ct, Co), two inductors (Li, Lo) , a switch (S) and a diode(D). If we talking about the working of cuk converter so it operates in two modes first is when switch is on and second one is when switch is off. When switch is on the diode behaves as a open circuit the voltage stored voltage in coupling capacitor is shifted to the inductor, capacitors and the load at output side. At the time when switch is off diode behaves as closed circuit at that time the coupling capacitor is charged from the supply which getting from input and from the energy produced by the input inductor.



CIRCUIT DIAGRAM OF CUK CONVERTER

APPLICATIONS OF CUK CONVERTER

- To make the output voltage as constant source cuk converter is used
- It also used where voltage regulator is required
- In DC drives
- Cuk converters used in hybrid solar, wind energy system as a regulator
- Works as a power amplifier
- Automotive applications

ADVANTAGES OF CUK CONVERTER

- It gives constant supply of output and input current
- The sign of output voltage is reverse of input voltage
- Very high efficiency
- Works as both buck as well as boost converter
- Lower operating duty cycle
- There is no need to have the filter capacitor to reduce the output ripple.

3. MODELLING AND ANALYSIS

Modeling of cuk converter is little bit different from other converter because its configuration is changing according to change in switch operation .During switch On condition voltage and current equation can be obtained using KVL and KCLLaws which are represented below .The voltage across the inductor at source is given by

$$v_i = L_i \frac{di_L}{dt}$$

By applying KVL in loop 2 in Figure.3.1 we get the equation

$$\boldsymbol{v_i - v_{Co} = L_o \frac{di_{Lo}}{dt}}$$

Current passes through interlinking capacitor is given by

$$i_{Li} = C_i \frac{dv_{Li}}{dt}$$

Apply KCL for loop 3 in Figure 3.1we get

$$i_{Lo} - \frac{v_{Co}}{R_L} = C_o \frac{dv_{Co}}{dt}$$

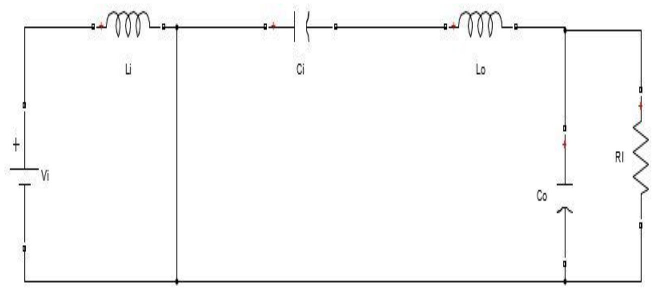


Figure. circuit diagram of cuk converter (switch on)

Equations during switch off condition are given below

By applying KVL in loop 1 in figure 3.2 we get

$$v_i - v_{Ci} = L_i \frac{di_{Li}}{dt}$$

Voltage across output inductor is given by

$$v_{Co} = -L_o \frac{di_{L_o}}{dt}$$

Current passes through interlinking capacitor is given by

$$i_{L_i} = C_i \frac{dv_{L_i}}{dt}$$

Applying KCL for loop 3 in figure 3.2 we get

$$i_{L_o} - \frac{v_{C_o}}{R_l} = C_o \frac{dv_{C_o}}{dt}$$

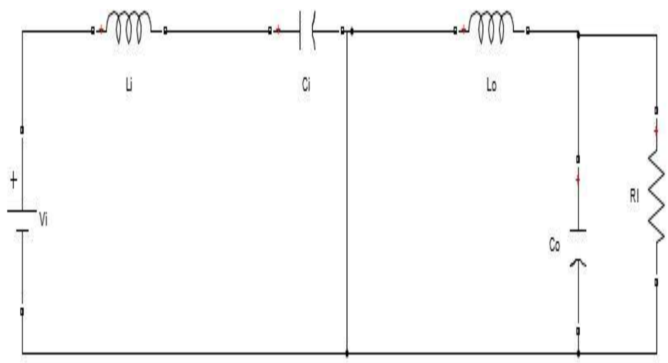


Figure .circuit diagram of cuk converter (switch off)

With the help of those current and voltage equation we define steady state space model for the system

At switch on condition $X = A_1X + B_1U$

$$\begin{bmatrix} i_{L1} \\ i_{L2} \\ i_{C1} \\ i_{C2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & \left(\frac{-1}{L_1}\right) & 0 \\ 0 & 0 & 0 & \left(\frac{-1}{L_2}\right) \\ \left(\frac{-1}{C_1}\right) & 0 & 0 & 0 \\ 0 & \left(\frac{1}{C_2}\right) & 0 & \left(\frac{-1}{RC_2}\right) \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ v_{C1} \\ v_{C2} \end{bmatrix} + \begin{bmatrix} \left(\frac{1}{L_1}\right) \\ 0 \\ 0 \\ 0 \end{bmatrix} [v_i]$$

$$\begin{bmatrix} i_{L1} \\ i_{L2} \\ i_{C1} \\ i_{C2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & \left(\frac{1}{L_2}\right) & \left(\frac{-1}{L_2}\right) \\ 0 & \left(\frac{-1}{C_1}\right) & 0 & 0 \\ 0 & \left(\frac{1}{C_2}\right) & 0 & \left(\frac{-1}{R_L C_2}\right) \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ v_{C1} \\ v_{C2} \end{bmatrix} + \begin{bmatrix} \left(\frac{1}{L_1}\right) \\ 0 \\ 0 \\ 0 \end{bmatrix} [v_i]$$

$$\begin{bmatrix} i_{L1} \\ i_{L2} \\ i_{C1} \\ i_{C2} \end{bmatrix} = \begin{bmatrix} 0 & 0 & \left(\frac{-1}{L_1}\right) & 0 \\ 0 & 0 & 0 & \left(\frac{-1}{L_2}\right) \\ \left(\frac{-1}{C_1}\right) & 0 & 0 & 0 \\ 0 & \left(\frac{1}{C_2}\right) & 0 & \left(\frac{-1}{RC_2}\right) \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ v_{C1} \\ v_{C2} \end{bmatrix} + \begin{bmatrix} \left(\frac{1}{L_1}\right) \\ 0 \\ 0 \\ 0 \end{bmatrix} [v_i]$$

$$\begin{bmatrix} v_o \\ i_i \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} i_{L1} \\ i_{L2} \\ i_{C1} \\ i_{C2} \end{bmatrix}$$

At switch off condition $X = A_2X + B_2U$

Output equation $Y = CX + DU$

So the system equation for cuk converter is given by

$$\frac{v_o}{v_s} = \frac{1.561 \times 10^{16}}{s^4 + 40070s^3 + 5.509 \times 10^9 s^2 + 2.083 \times 10^{12} s + 1.041 \times 10^{16}}$$

Above equation is the transfer function of the system which we used in matlab for tuning the PID Controller.

4. MODEL OF CUK CONVERTER WITH PID CONTROLLER

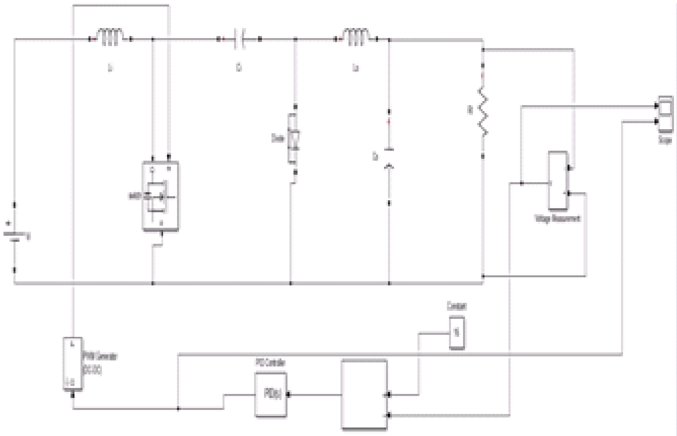


Figure 4 cuk converter with pid controller

- This diagram is only for given input values to the controller and for the output values of the converter
- For simulation another diagram is used which is shown below

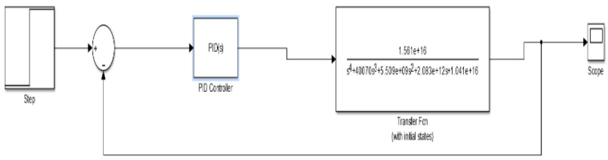


Figure: simulation model

5. SIMULATION AND RESULT

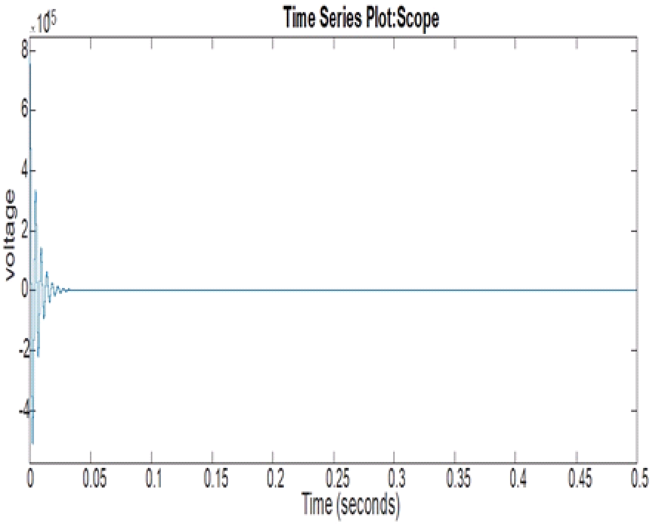


Figure 5.1 output of cuk converter with pid

The model consist of summation block step input for calculating error and pid controller for Control the action and a scope to show the output

PARAMETER OF CUK CONVERTER WITH PID (FIGURE 4) USED ARE:

Vi	12v
Vo	18v
R	8.1
Li	432 microhenry
Lo	649 microhenry
Ci	17.8 microfaraday
Co	3.08microfaraday
D	0.6

Parameters of cuk conveter with PID

5.1 TIME DOMAIN ANALYSIS

Any system can be represented with reference to function of time is called time domain analysis .The below figure are the output of pid controller after performing simulation in matlab .Usually the output of the system can be represented in two states transient state and steady state . The steady state time depends upon the input of the system where as transient state time depends on the poles of the system.

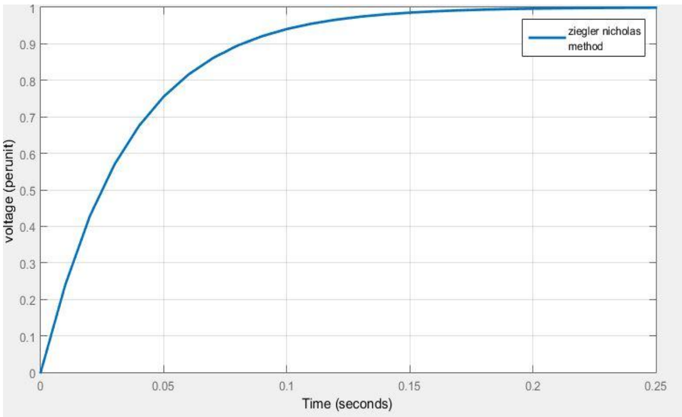


Figure 5.1 output response of ziegler nicholas method

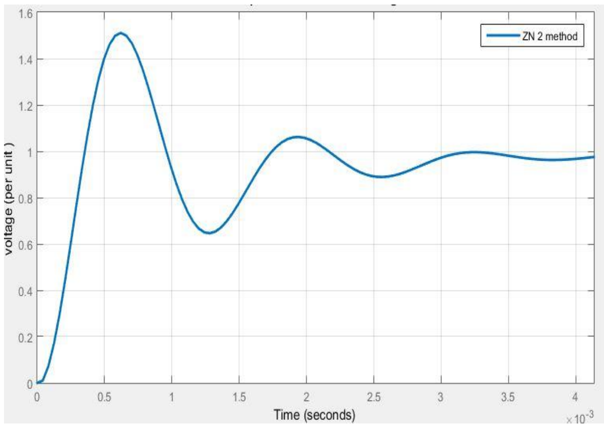


Figure 5.2 output response of ziegler nicholas method 2

5.2FREQUENCY DOMAIN ANALYSIS

Analyzing the transient state and steady state response in term of frequency and phase called frequency domain analysis .This method is known as bode plot .there is a criteria for telling the system is stable or not by using phase margin and gain margin values .The system which are having high phase margin value then the gain margin are considered as stable system

Below figure are the result of simulation in the matlab software

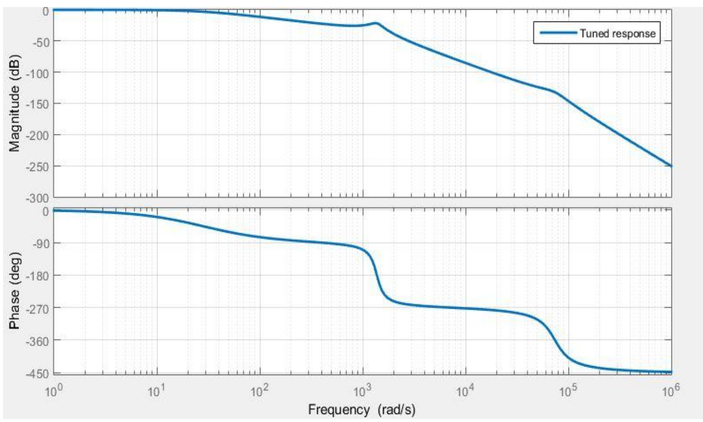


Figure 5.3 stability response for ziegler nicholas method 1

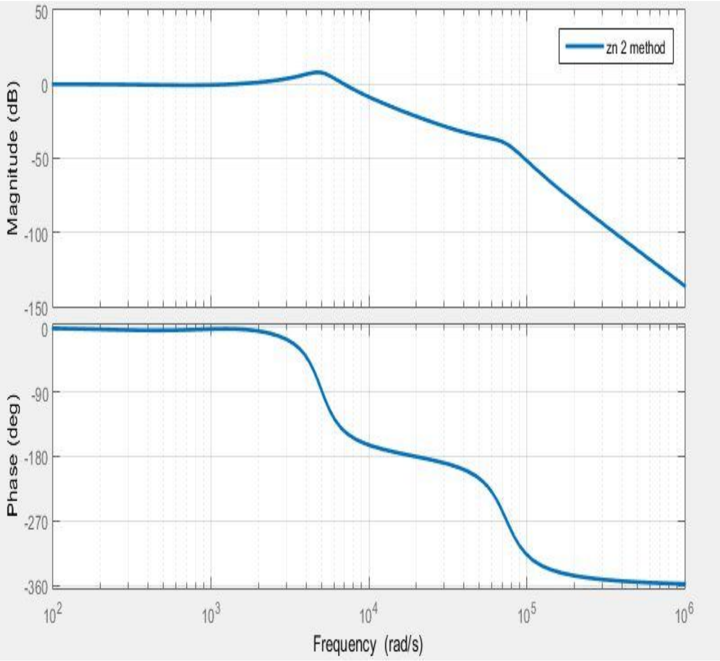


Figure 5.4 stability response for ziegler nicholas method

Method name	Kp	Ki	Kd
Ziegler Nicholas	0.0011563	0.000577995	0.00057839
Ziegler Nicholas 2	.994	2307	0.001283

TABLE 5.1.PID gain values

6. CONCLUSIONS

Here two PID tuning method are compared in time and frequency domain responses So that we can design the best controller for cuk converter .By comparing the simulation Result of these two method we can find out that ZNM method gives the best response in Comparison to ZNM 2 .Also ZNM take more response time but overall values are the best.

Such as it has more PM value then the GM which gives the stable system in comparison to ZNM 2 .so it can be concluded that ZNM is best method for designing a controller for CUK
Converter.

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