**Control and Tuning Methods in Switched Mode Power Converters**
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Module - 04
Variable Frequency Control Methods
Lecture - 20
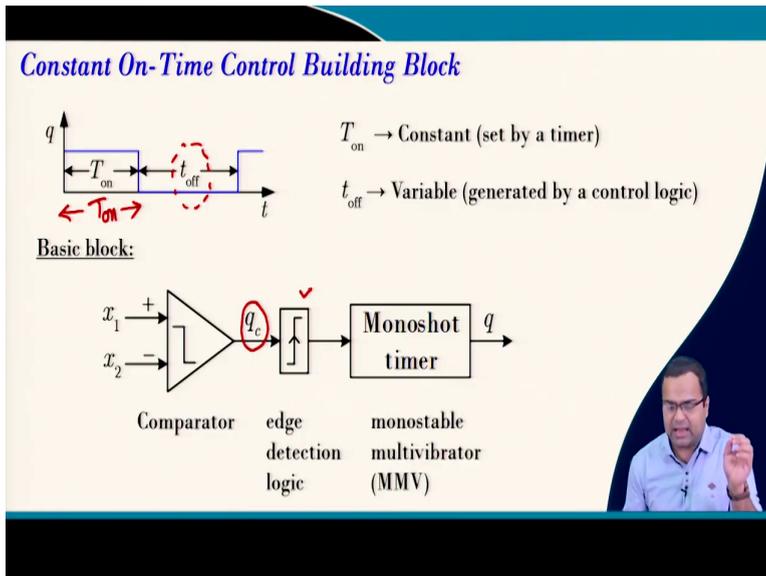**Constant On-Time Control Methods**

Welcome, today we are going to take lecture number 19. In this lecture we are going to discuss Constant On - Time Control Method.

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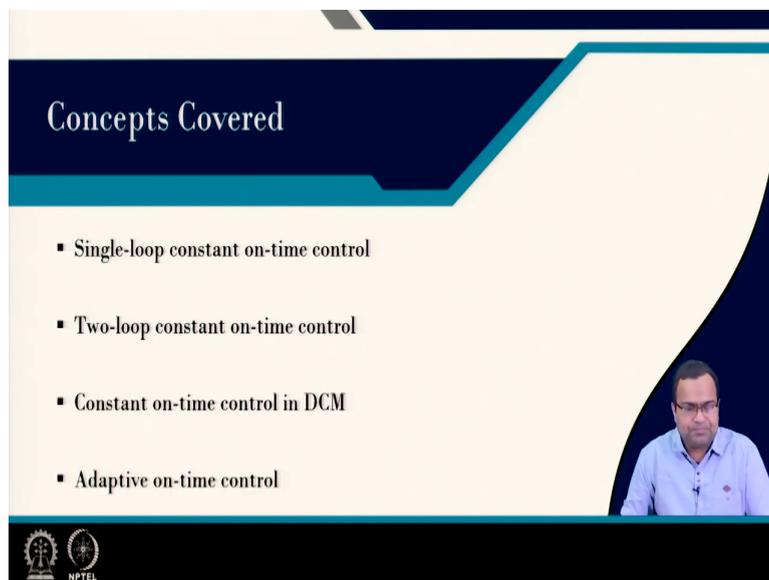
And I am going to first talk about single-loop constant on time control, two- loop constant on time control, constant on time control in discontinuous conduction mode and adaptive on time control.

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So, in constant on time control, I think earlier in week 2, we learn about constant on time modulation. So, we already know about the basic concept of constant on time modulation and today we also want to show I want to show the MATLAB building block, how to build constant on time. And we will identify there are you know there is a problem in constant on time control. So, we need to incorporate minimum off time.

First constant on time, if we take the gate signal, this is the gate signal q in this gate signal that instead of duty ratio we will take this on time, this is my on time and this on time is constant. And the smaller time indicate this is the off time which will be adjusted from the feedback loop ok.

So, a building block; that means, if we take two signal x 1 and x 2, here two signals are compared and the comparator output q c actually the edge positive edge of this q c is detected. And then this output goes to a monoshot timer and the monoshot timer gives us the actual gate signal, ok. So, it is a comparator, now it required an edge detection circuit and monostable multivibrator.

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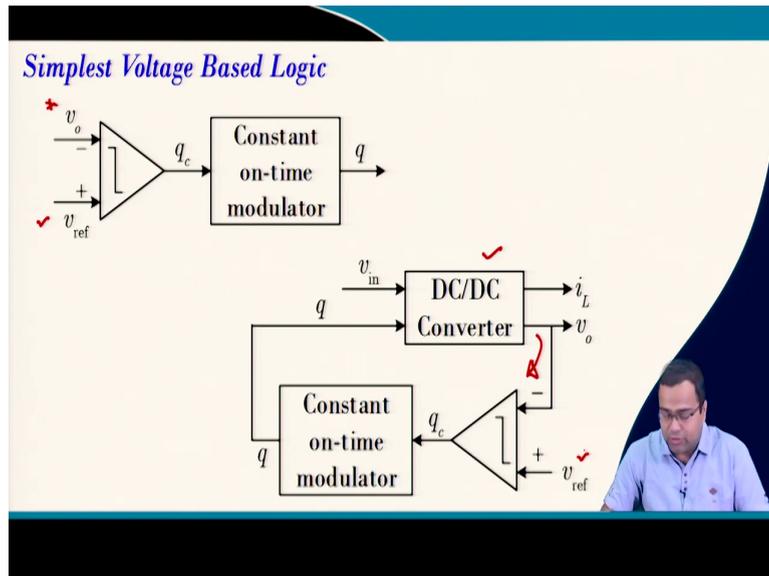
The simplest voltage based logic. So, here we are going to consider the output voltage and the reference voltage. So, the output voltage and reference voltage both are compared. This is our output voltage, and this is our reference voltage. Both are compared. And the output of the comparator, which is q c that actually goes to the constant on time modulator.

How does it work; that means, if we take a single loop feedback control, this is a DC-DC converter and you can take any DC-DC converter. So, in the example case study we are going to take a buck converter, but you can take boost as well as other converter as well. So, here, we are taking the feedback loop. This is my feedback loop and output voltage is directly compared with the reference voltage. This is my reference voltage. And the comparator output goes to constant on time modulator.

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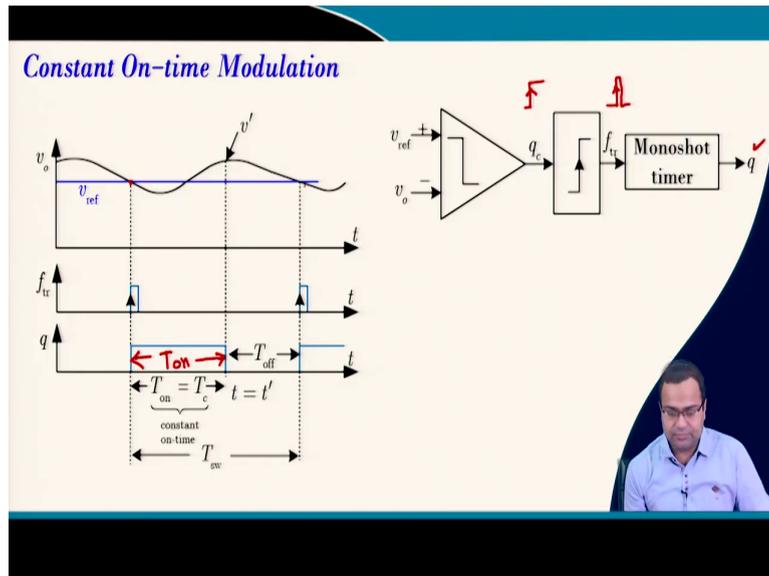
Now, we discuss the very simple basic constant on time modulator. Suppose this is the waveform. Here we are going to show the output voltage when it crosses; that means, it's try to go below the reference voltage. That means, if the output voltage goes below reference voltage, then we can find a positive edge of this; that means, it goes high and this edge detection detects a positive edge here. That means there will be a positive edge when there is a when the output voltage tries to go below the reference voltage.

Then this trigger the monoshot timer and the monoshot timer is loaded with a constant on time; that means, a fix value and this is my constant on time. So, this is the duration of on time when the switch is on and this value is loaded in the constant on timer.

So, I will go, I will show you the MATLAB implementation of this logic. Once the on time is elapsed that means the timer finishes it is counting then it turns switch turns off, this q goes low and then output voltage again tries to decrease again when it crosses v ref then switch turns on ok.

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But in this method, let us consider a scenario where the converter undergoes a load step up transient. That means the load current has increased. So, let us say at this point there is a change in load state; that means, it undergoes a load step transient of delta i 0, earlier it was i 0, now it is i 0 plus delta i 0 that is a load current. So, first thing what happens if v 0 is less than v ref; that means we know the logic when output voltage crosses; that means, this is the direction of output voltage it crosses v ref the monoshot timer detect.

That means the edge detection circuit detects a positive edge. This is the edge detection circuit output. And this turn on, this enables this monoshot timer and the monoshot timer goes high for the duration, which says by it constant on time and then it turns off. When it turns off, then because there is a load step of transient in general in under steady state, it is supposed to increase the output voltage.

That means the output voltage was supposed to increase and it should go above v ref that was our traditional waveform under steady state. But because of the load transient step-up transient, the capacitor current is negative for a certain duration when the output cannot increase. So, it will decrease. So; that means, in this time v dash the output voltage is lower than v ref. So, the output of the comparator remains high at high and we cannot get any positive edge here.

Then what will happen? Then we cannot turn on the timer again; that means, the timer cannot turn on as a result no on time; that means, the switch remains off. That means, if v dash is less than v ref this is my v dash ok. At t equal to t dash then what will happen? The q c

remain high and no rising is detected and this will cannot this cannot enable the timer. This monoshot timer cannot be enabled. As a result, the q gate signals remain low or it is turned off, it remains off. Then the output voltage will further decrease and ultimately voltage will collapse.

So, this process of simple constant on time implementation cannot be used in general circuit because it will lead to the collapse of the output voltage, particularly during load step-up transient.

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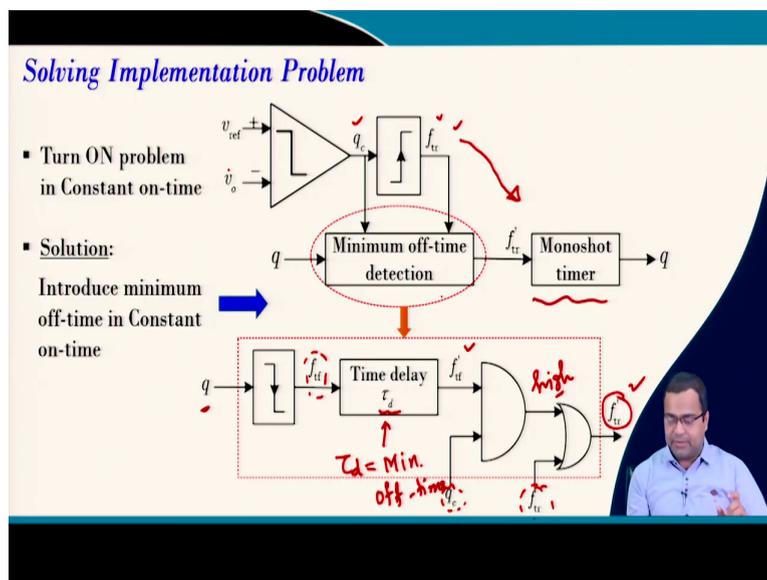
So, that is why in most of the commercial products, in order to solve this problem, what do we have to do? We have to introduce a minimum off time. After that we need to check the status if after a certain that means, once the switch is turned off, it will wait for certain time and check whether the comparator output is still remain high or not. If it is high; that means, output voltage is smaller than reference voltage, then we have to provide another trigger pulse to turn on this monoshot timer ok.

That means, how does it work? So; that means, this part is a minimum off-time that should be introduced and that we have discussed in the very previous class in week 2, how does it work? So, we should check the status of the gate signal ok; that means, when the switch was on; that means, the monoshot timer was high, then at some point when the timer finishes its timing value or the counting value. Then the switch turns off and that time you detect a falling edge of the switching signal.

This falling edge is delayed by a time tau d and this delay can be realized using a shift register. So, this is a delayed edge detection signal which detects a negative edge of the switching gate signal and that is delayed by tau d. And this delay time is nothing, but this tau d is nothing, but our minimum off time we will discuss ok.

So, then it checks with the output of the comparator as I said after this delay time if that the comparator output is high; that means, our v 0 is less than v ref it indicate we need to turn on the switch because output voltage is going down. So, this is high, then this output will go high, this will go high at this time and then it actually it is also ended with the actual trigger signal.

So, that if either of them is high, this will go high, if any edge is detected either the edge of the rising edge or the delayed falling edge is any of these edge detected high edge this edge is now used for the monoshot timer. That means earlier we are using this was our earlier trigger pulse, but now it is modified by introducing a minimum off time, ok.

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So; that means, the turn on problem in constant on time we need to identify the falling edge of the gate signal, then we need to delay and then we need to AND with the output of the comparator. And this will actually OR, the output of the AND gate is OR-ed with the original rising edge of the trigger pulse and then the resultant output of the OR gate that is the resultant trigger pulse is used to trigger the monoshot timer ok.

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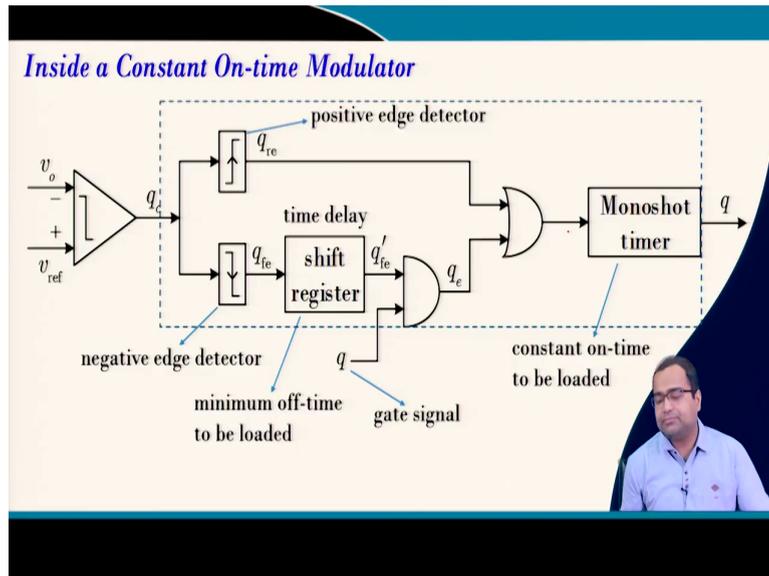
So, inside a; that means, monoshot timer we have a shift register, and this is this what we have discussed positive edge detection, negative edge detection, a time delay, a gate signals require a minimum off time to be set and the constant on time to be loaded.

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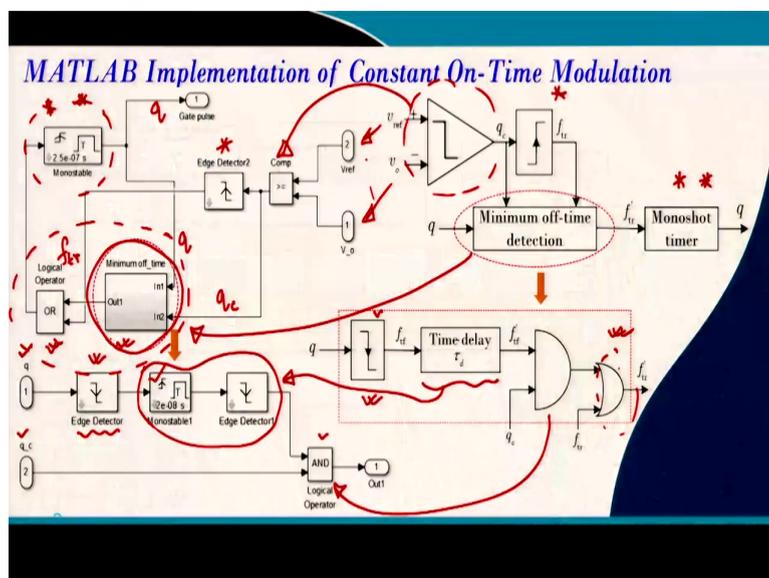
So, how to realize in MATLAB? In MATLAB, this can be realize by this comparator. You can see this comparator is nothing, but this comparator ok and MATLAB you will get the greater than less than the equality sign. Here, if we v ref is greater than v 0 that logic is implemented here, this is the reference voltage, this is the output voltage in the MATLAB.

So, first edge detection circuit this circuit is realized here and the minimum off time generation is the whole circuit here. So, this is the minimum off time generation circuit this is here and what is the input to the minimum off time?

The one input you can see is the output of the comparator, that is a q c; that means, this is my q c, the other input is the gate pulse which is q; that means, this is also q the other input is q. And for the OR input, we are using the f_tr that is rising you know edge detection circuit. The output of the positive like rising edge detection circuit and this is ORed.

And this is actually the original monoshot timer; that means, if I take about this one. So, this is this block and in MATLAB we can get this monostable where the on time will be set according to the on time constant on time value and if we go inside this block, what is this? That means this is analogues circuit in the schematic and this is a MATLAB implementation.

Now, what is there inside this block? So, this block I am talking about this particular block, if you take this block again, it takes q and q c as the input and q c directly ANDed that we know.

And there is a negative edge detection circuit which is nothing but this one; that means, if we take this one, this is our negative edge detection circuit. And this delay time is realized by these two blocks in the MATLAB, this is my delayed signal is realized ok. And then this is the AND gate and the overall thing is ORed here; that means, this is an OR signal, and this is our OR signal ok.

So, this we can implement the MATLAB and I will show you how to realize in MATLAB. Now; that means, if we go back to the MATLAB.

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Let us go back to the MATLAB.

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I want to show you the implementation of constant on time ok.

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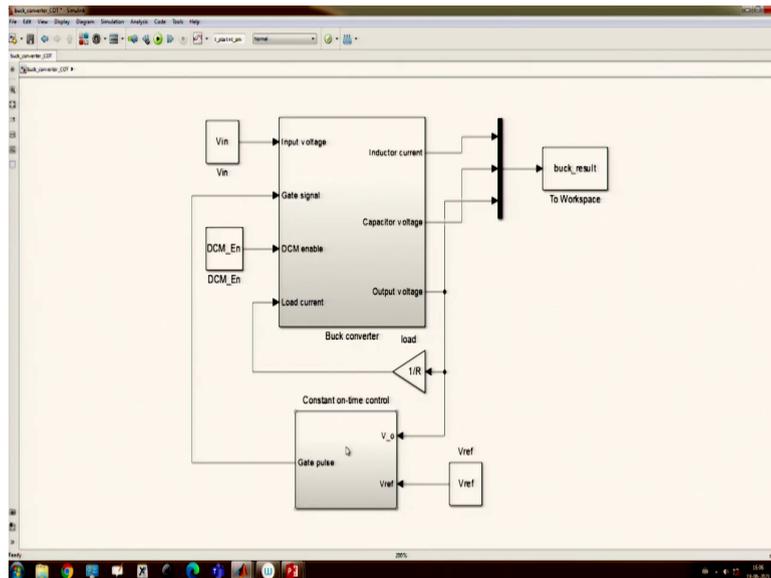
So, this converter block we already discuss; that means, you know this converter we have already discussed. And DCM enables everything we else we have discussed in the input voltage. You know how to make this model and this is your load resistance, resistive load. We can use any other load also, let us take it a little bit this side ok. This is a resistive load and then this is a constant on time control if you go inside, which we have discussed now ok.

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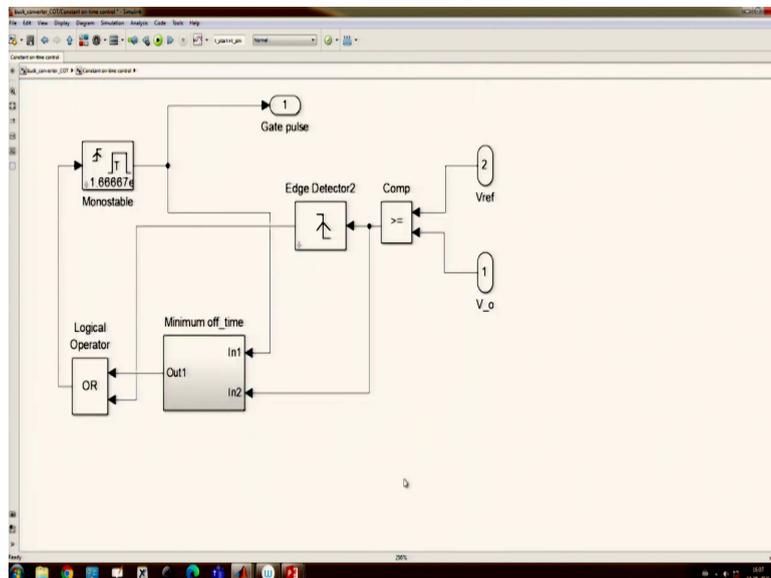
So, here what are you doing? Two reference signals and volt output voltage they are compared. This is the first positive edge detection circuit. And this whole block actually implement that delay time. That is the minimum off time, then this is the actual monostable

multivibrator. If you go the constant on time you can set it from here and this is a gate pulse ok.

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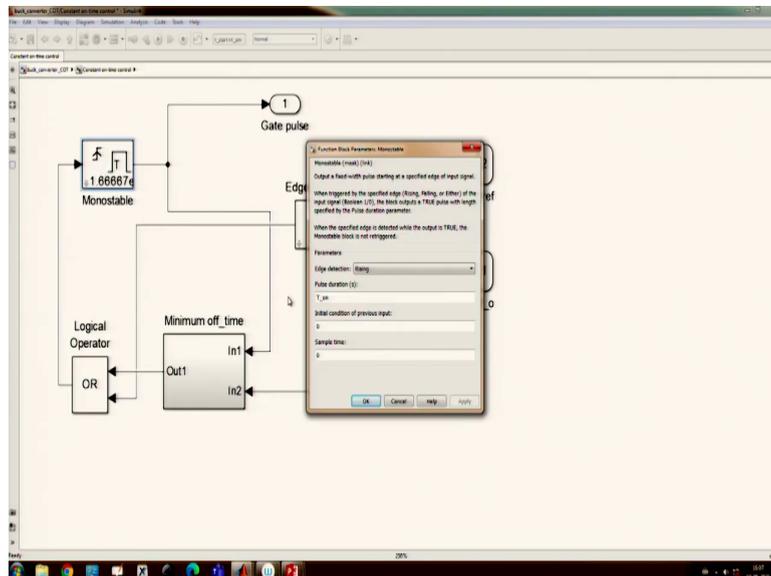
So, we can check this simulation by using this constant on time in the simulation model.

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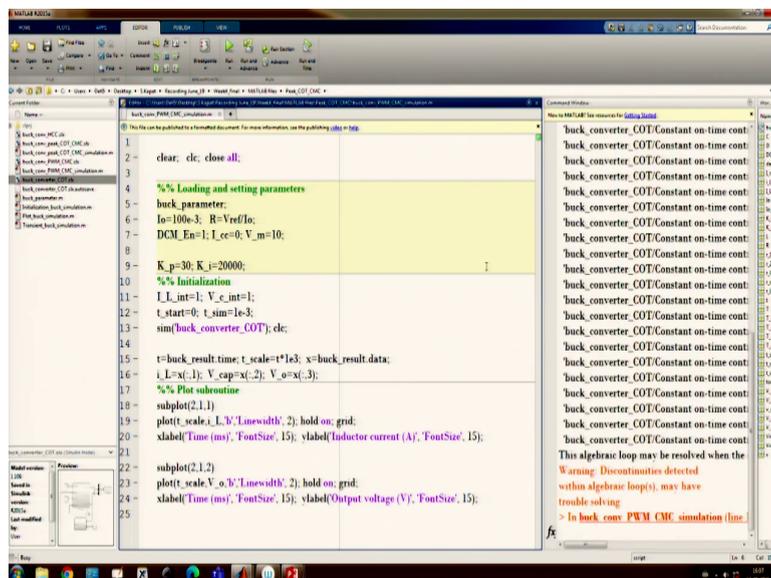
So, we can use a DCM enable to be 1 under discontinuous conduction mode, you can use 100 milliampere current and let us see how does it work.

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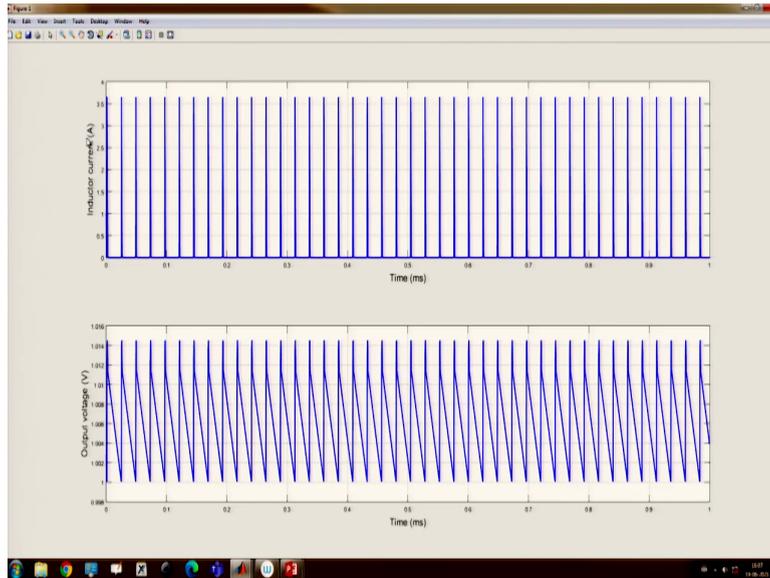
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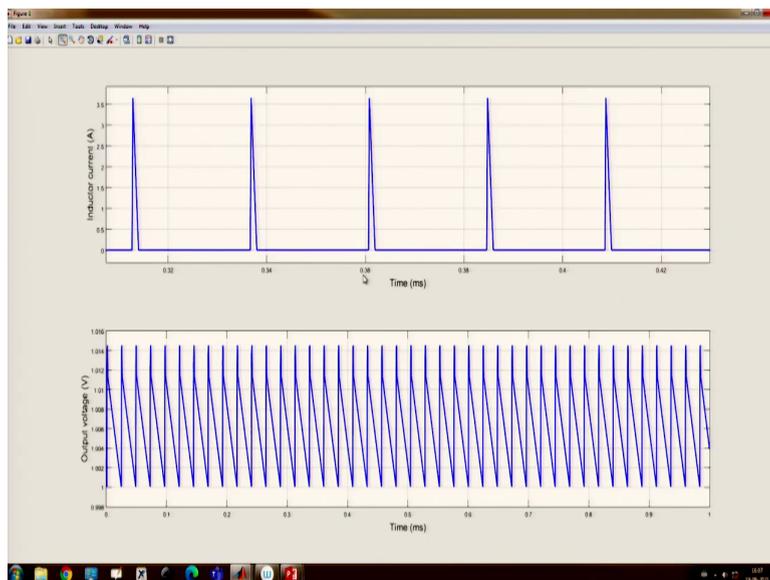
So, you can see this is a constant on time where the switching frequency will vary.

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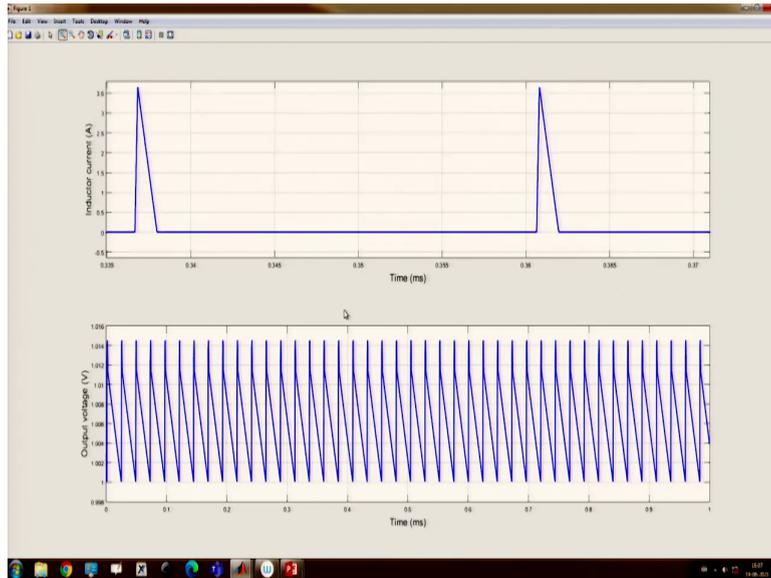
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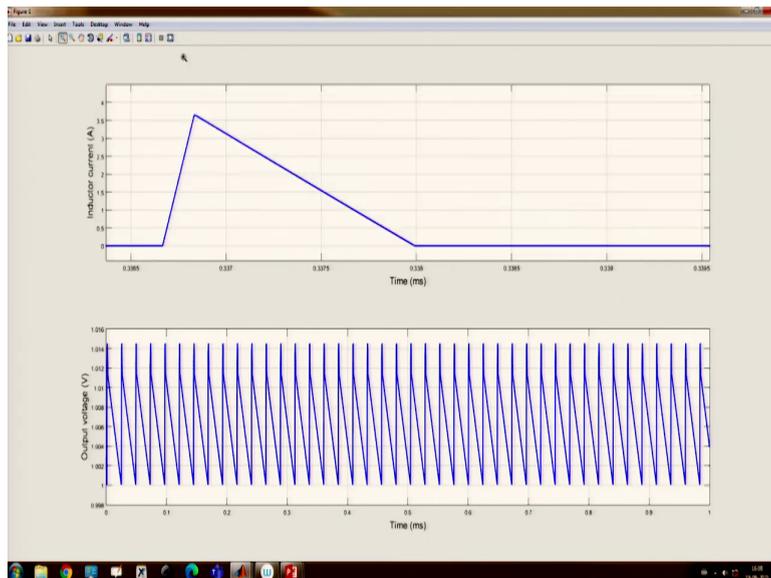
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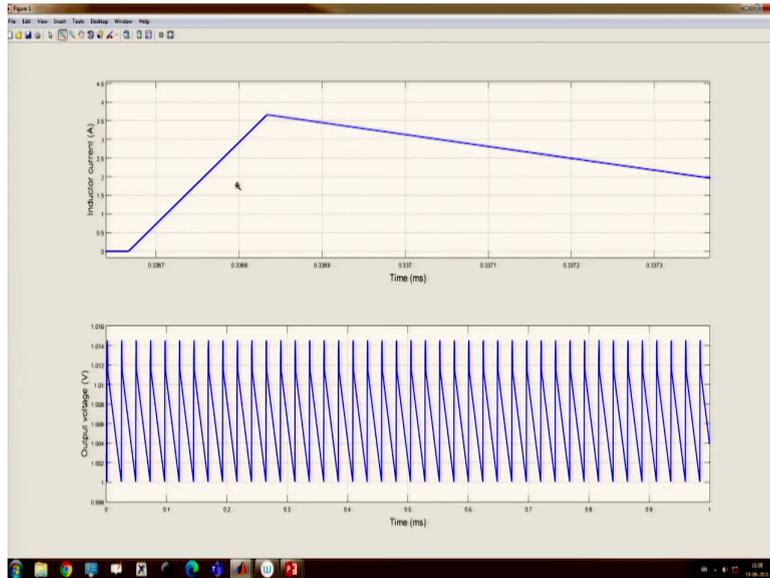
So, you can see this is a constant on time which is set and we can decide based on our requirement.

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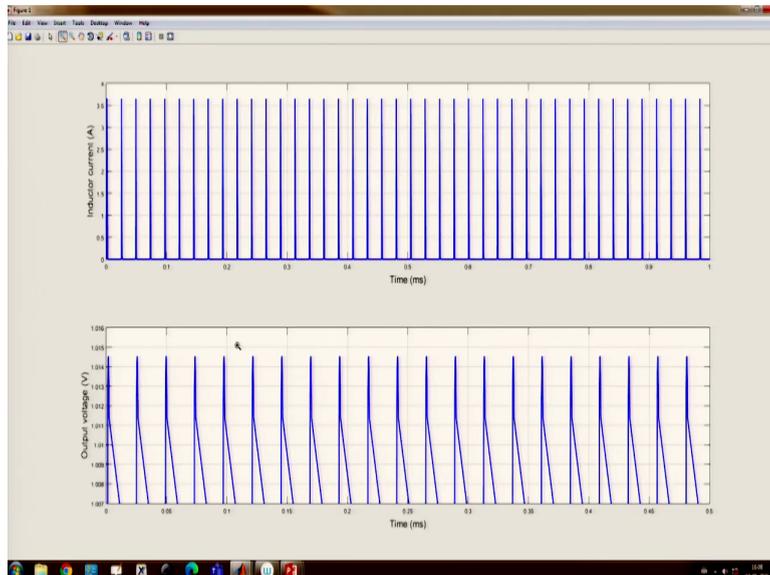
But, interestingly you will find, how does it work this logic?

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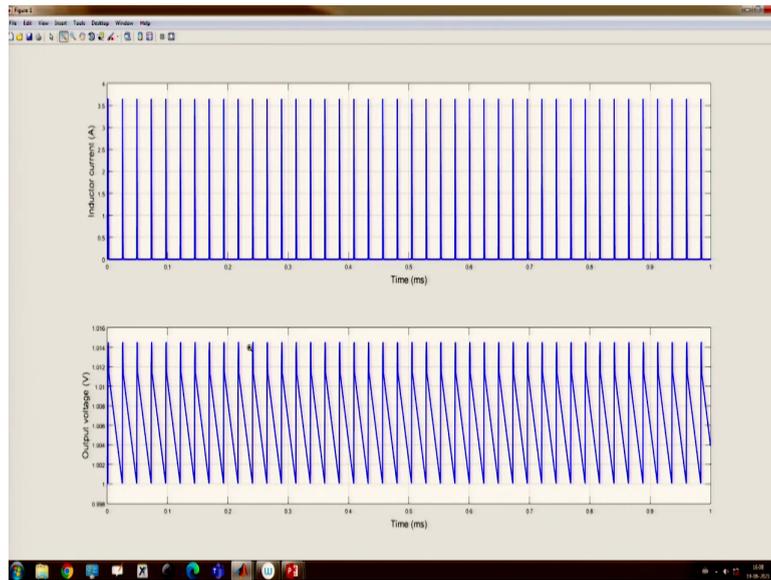
If you zoom this one of the cycle output voltage cycle.

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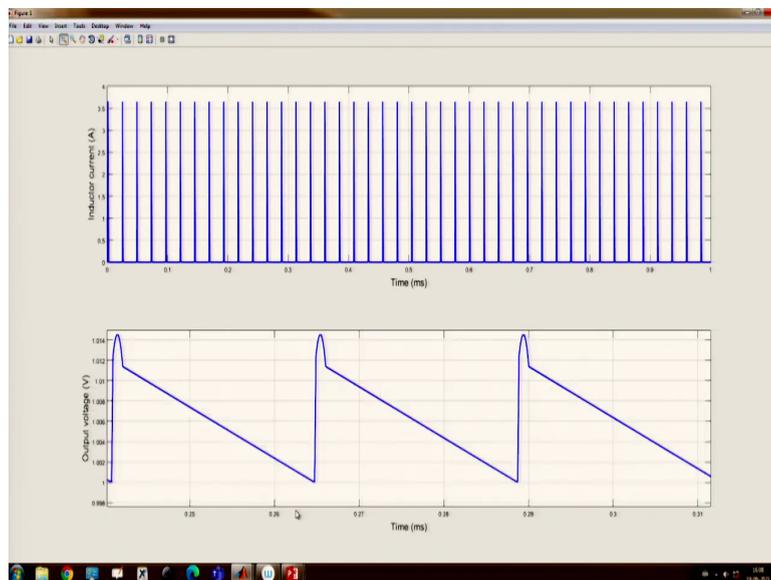
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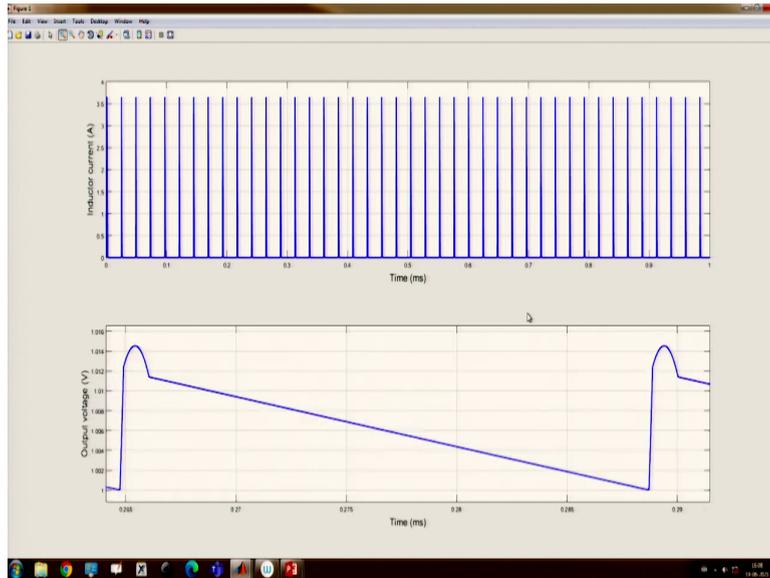
So, initially whenever the output voltage.

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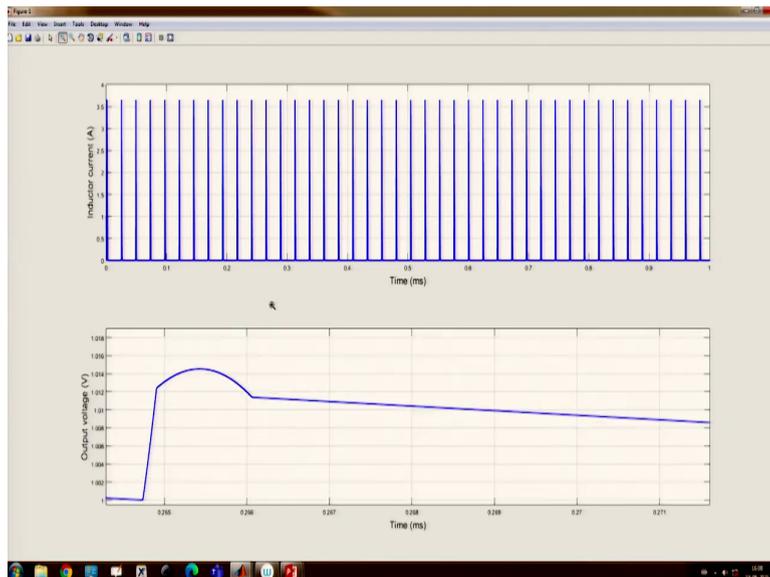
So, if we check that whenever the output voltage tried to cross this particular reference voltage which is one volt, then switch turns on and that turns on for certain on time duration.

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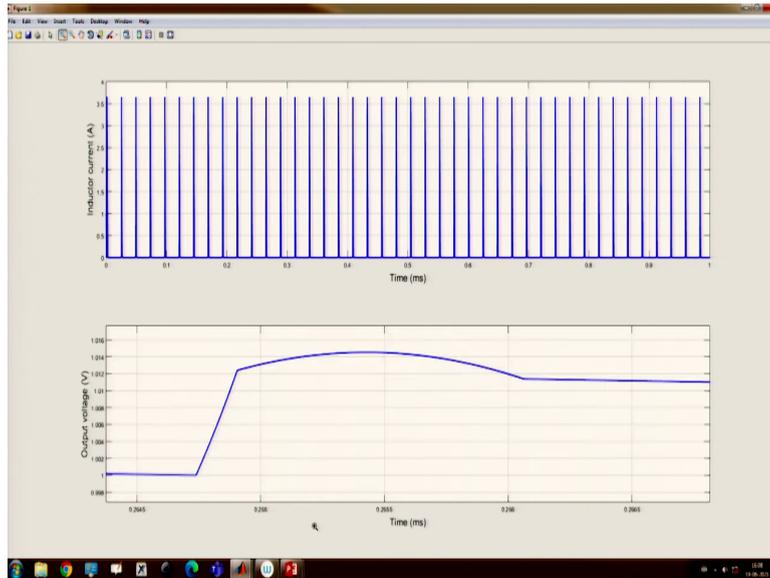
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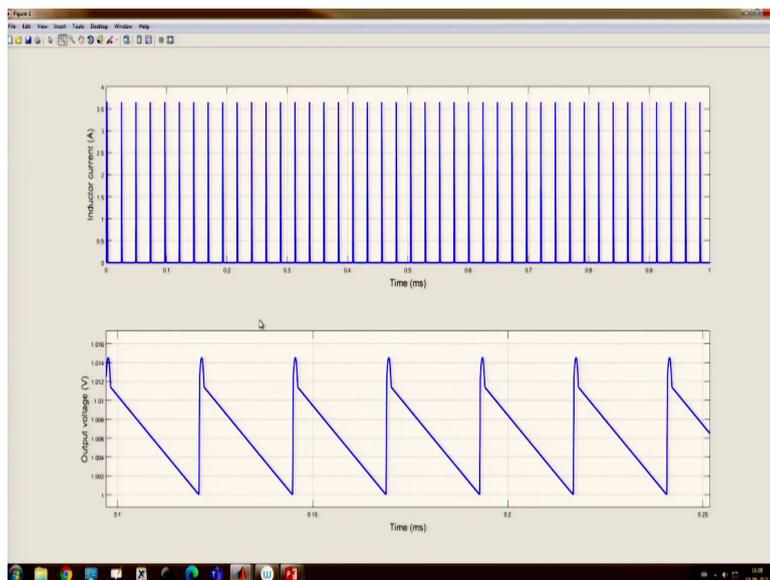
And then ok, if I take let us say this is my duration.

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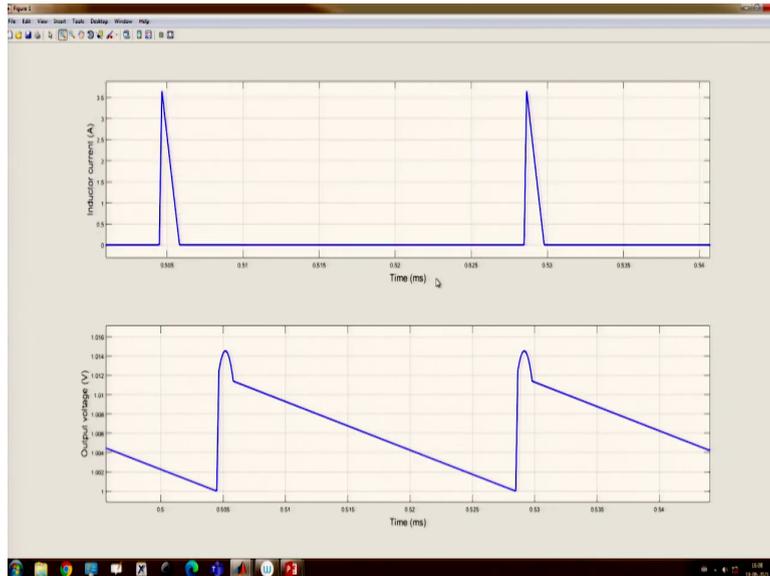
Let us say if we take around 0.5 ok one cycle you can take, so around 0.5 let us take ok.

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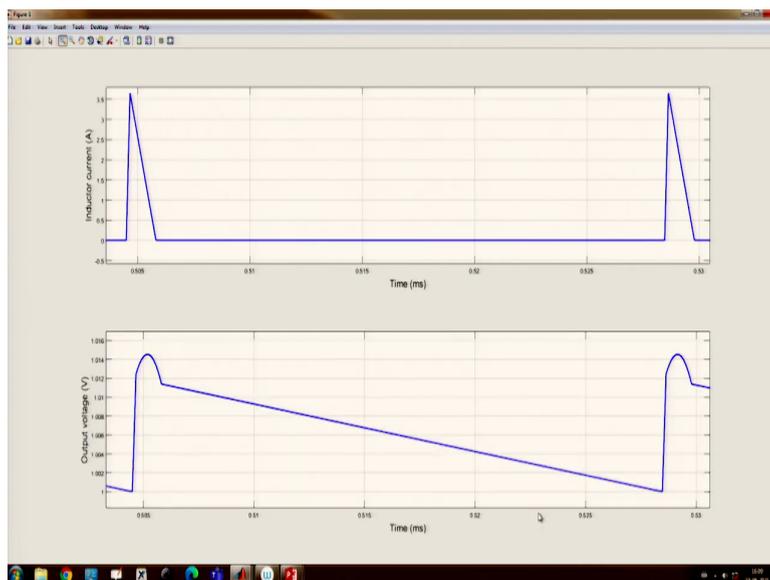
So, we will take from 0.505 to 50 here and I take here 505 to 5053 ok. So, you see, whenever the output voltage actually tried to cross this reference voltage here then switch turns on for a fixed on time duration. Then whenever the on time is elapsed, the switch turns off it hit the 0 current discontinuous conduction mode. And output voltage actually slowly decreases because the load current is very low whenever again it hit then again it turns off.

So, this process the constant on time logic part in this process; that means, now we understood that how does it work?

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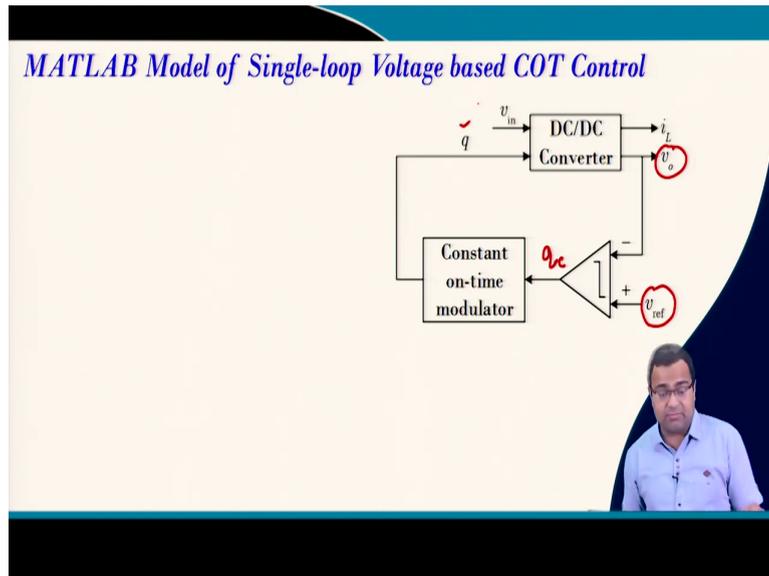
The next part is that ok, so now, we have implemented the single loop voltage mode control where this output voltage here now output voltages compared to the reference voltage and then the comparator output goes to the modulator. And then modulator generates the gate signal and that turn on and turn off the DC-DC converter.

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Now we want to simulate like you know we have already implemented this for constant on time control. We want to simulate for different input voltage. That means our reference voltage is 1 volt input voltage is 15 volt and then input voltage again is 8 volt and our load

resistance is 0.1 that means, hundred you know 0.1 ohm. This is for continuous conduction mode ok.

Then we will also run the steady state condition at different load current then we will do transient simulation ok. Let us first go to the MATLAB and check ok. So, what are you going to discuss the first condition we will take where input voltage is 15 volt and 8 volt for R equal to 0.1 ok let us go there?

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So, if I take R equal to 0.1; that means, let us take directly R equal to 0.1. So, I have already explained this MATLAB implementation. So, I am not going to repeat this and this controller in this case does not make any sense because we have not provided any controller here, you can see if you go inside there is no controller here it is just a simple input and output comparison. Then so, R equal to 0.1 ohms. So, initially we want to run for one condition which is V in equal to ok 15 volt.

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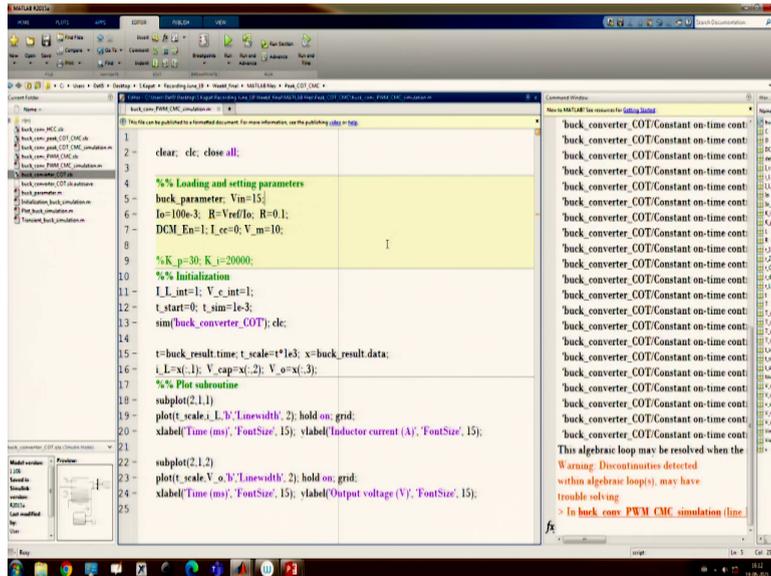
That means, here we will set V in equal to 15 volt let us run it.

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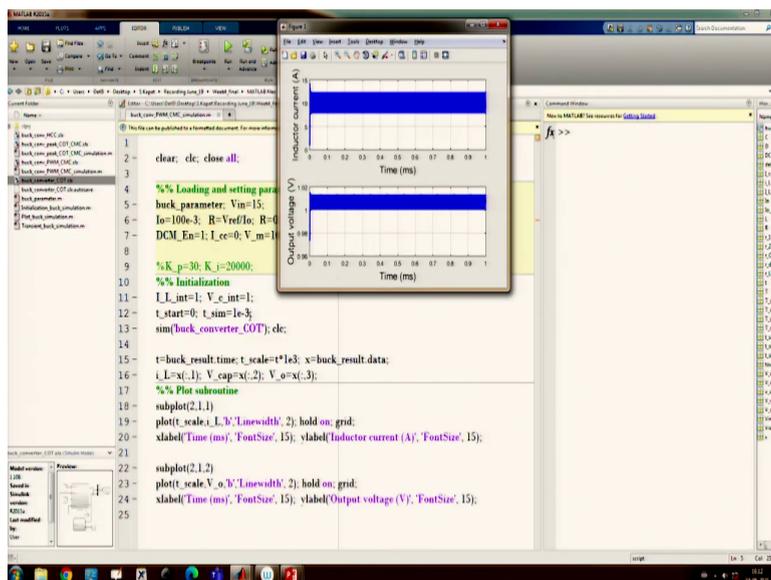
So, we want to show this is for V in equal to 15 volt and we want to overlap this waveform for V in equal to 8 volt ok.

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Now we are talking about V in equal to 8 volt and we want to repeat the simulation with the same load condition and check what happens ok.

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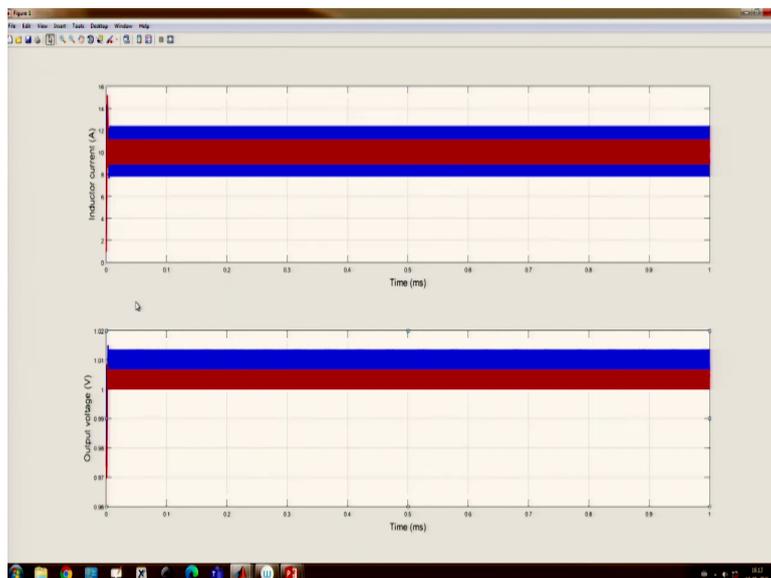
Now here, so here what can you find? First of all, if we take the inductor current around this time period.

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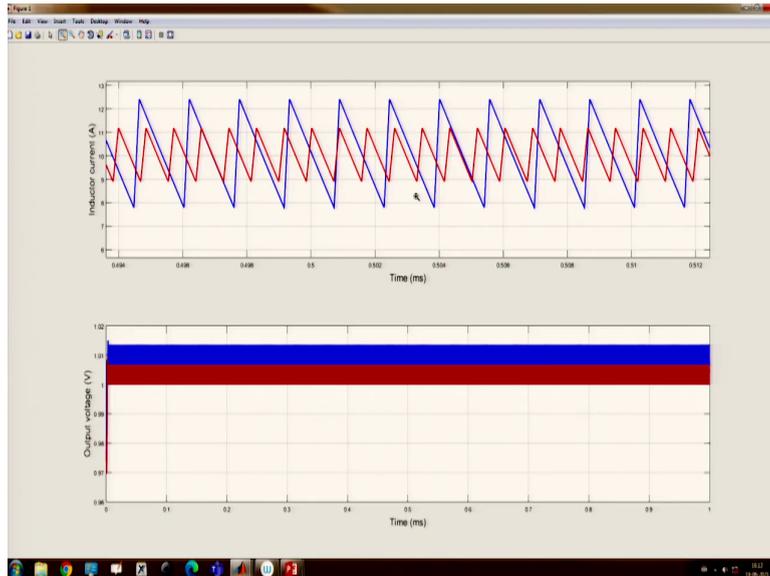
Let us say we are talking about from 0.5 millisecond to you know 0.51, 0.5 to 0.505 here.

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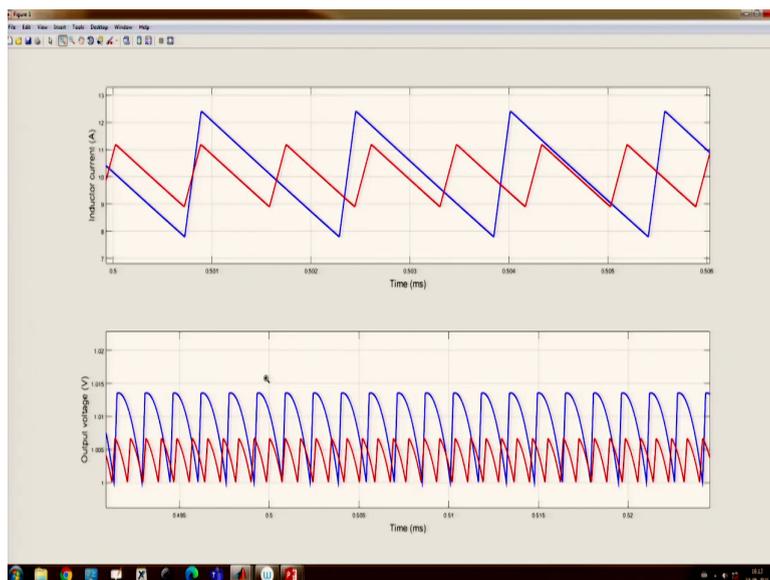
So; that means, in red colour we have decreased the input voltage which initially for the blue corresponds to the input voltage of just a minute. So, here we are talking about 0.5 to 0.506 ok.

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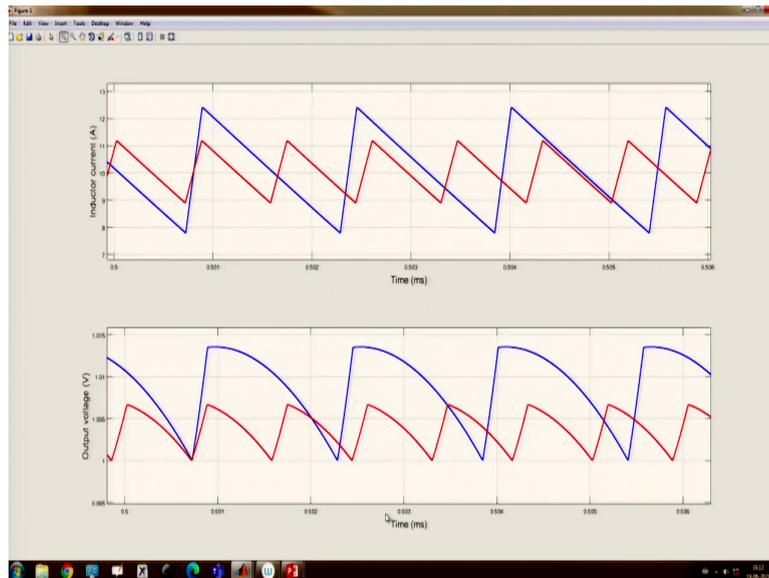
So, this red colour sorry blue one corresponds to 15 volt and the red one corresponds to 8 volt. So, what happened here? And in both the cases, the logic it looks like whenever you know reference voltage, the output voltage touches this V ref which is 1 volt. Then switch turns on and switch turns on for the given on time. So, in both cases, the on times are same, but since the first case blue one, the output voltage is higher; that means, for the same on time the current ripple will be larger.

Because the slope is higher, we can see the slope is higher because the input voltage is higher. In the red one, the slope is smaller and the same input voltage same on time the ripple current will be smaller. So, as a result the switching frequency is different for different input voltage condition ok alright.

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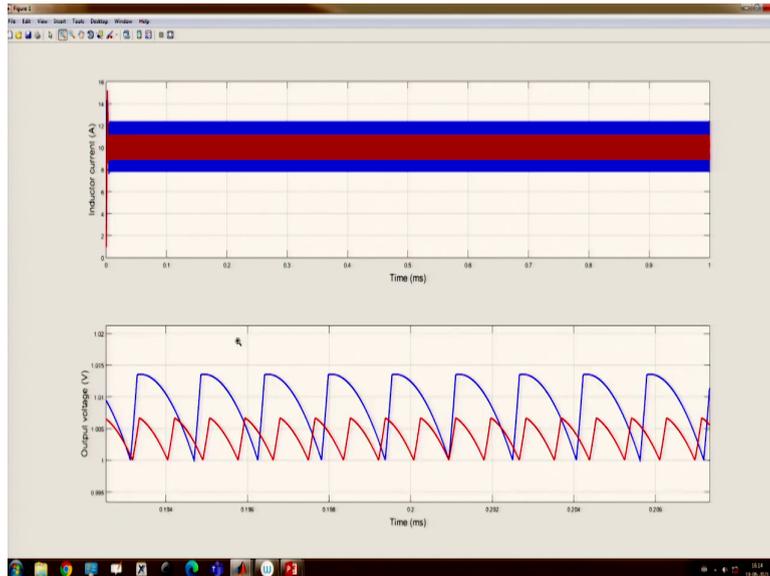
So, these two are for two different input voltage conditions ok. Now coming to the next simulation, we want another steady state condition where input voltage remains at 12 volt which is originally set in the parameter set. But we want to change the load resistance from 0.1 to 10 milliohm, 10 ohm ok, let us see what happens ok.

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So, we will change this now we are going to consider two different load resistance. So, in one case the load resistance is 0.1 which is let us say in the red colour.

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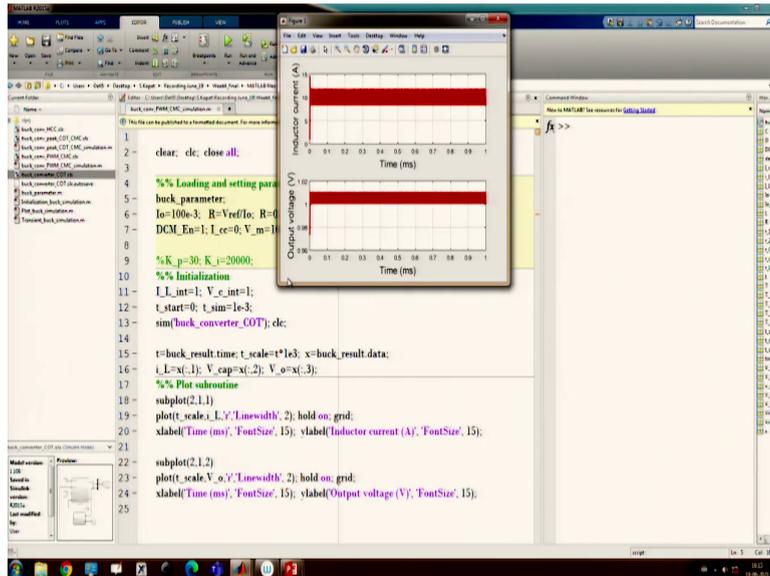
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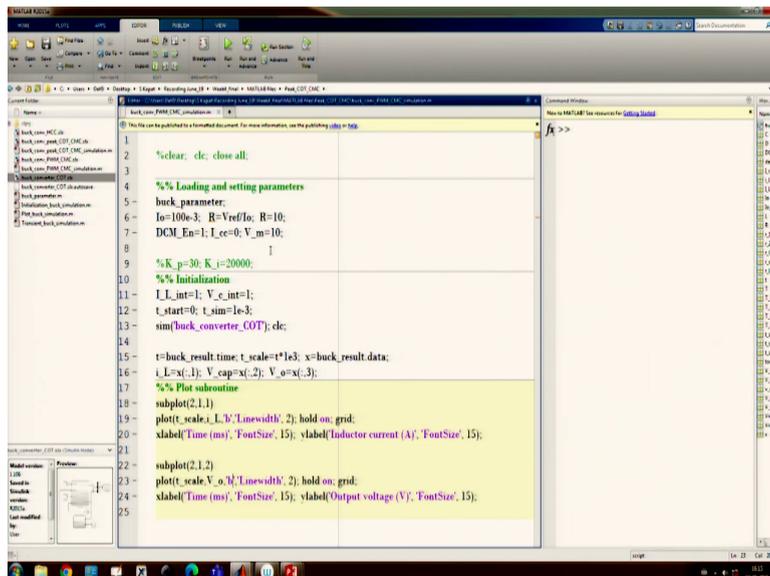
And in the other case we want to change it to 10 and we need to make it let us say blue colour, here the red colour, red trace corresponds to correct ok.

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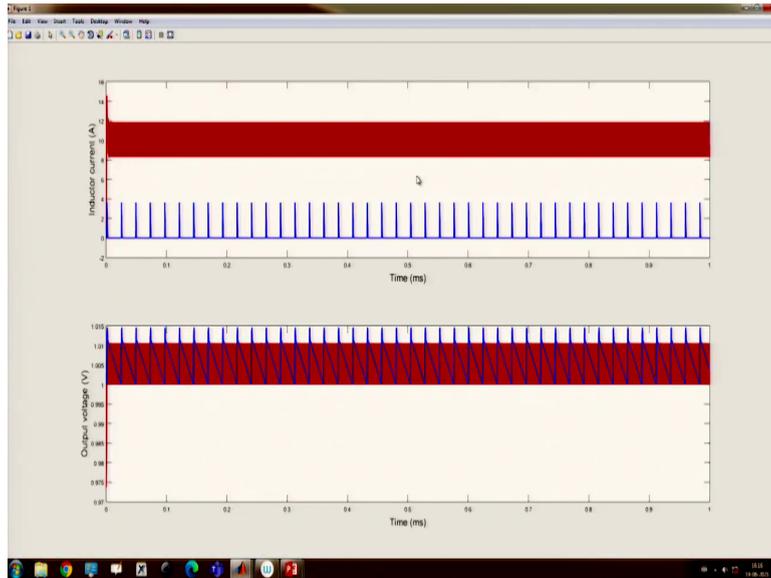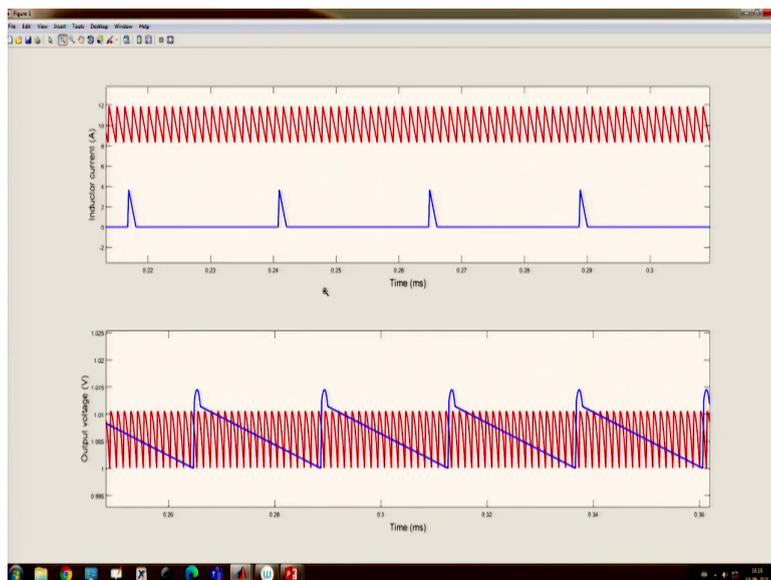
So, what we will find here ok, we zoom it.
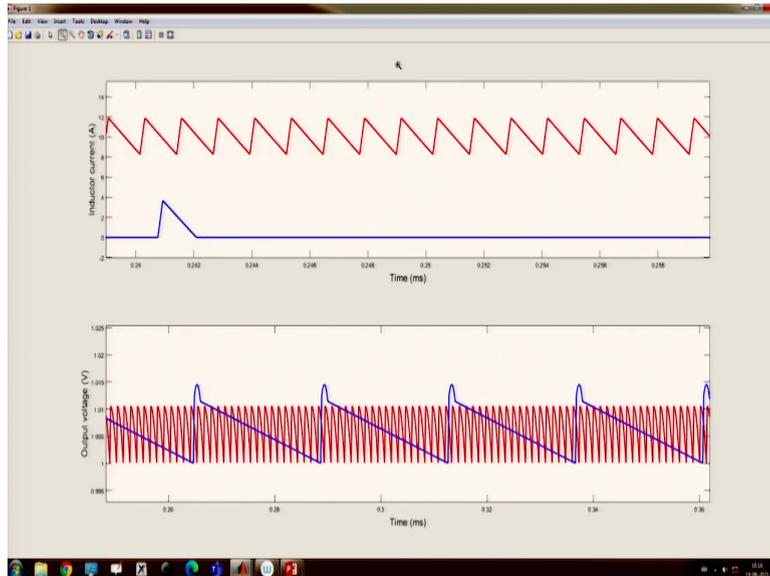
That means, under continuous conduction mode ok. Let us run it in CCM because we have enabled DCM.

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Let us continue in CCM ok.

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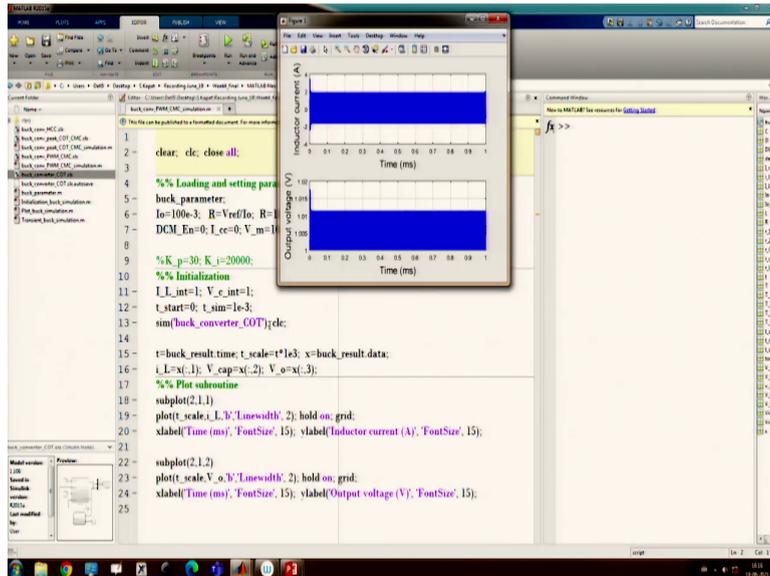
So, blue trace corresponds to ok, this is 1.

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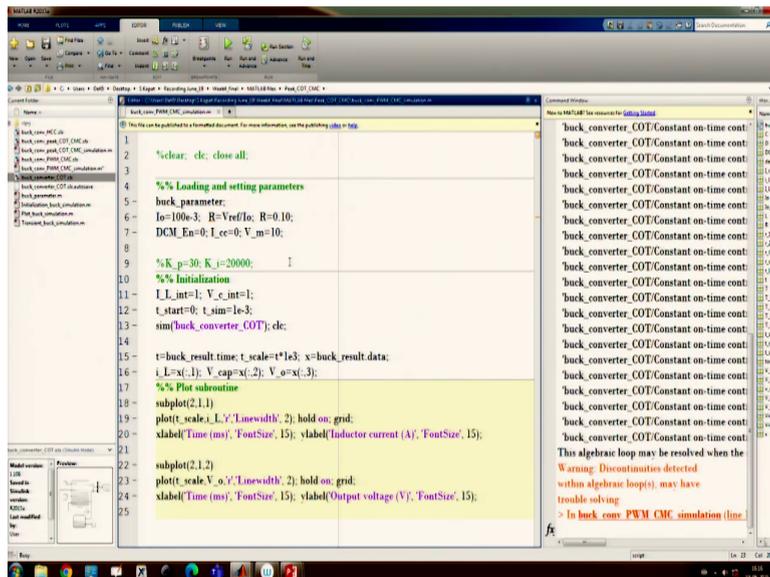
And the other one we want to do 0.1 and that corresponds to red trace ok, alright.

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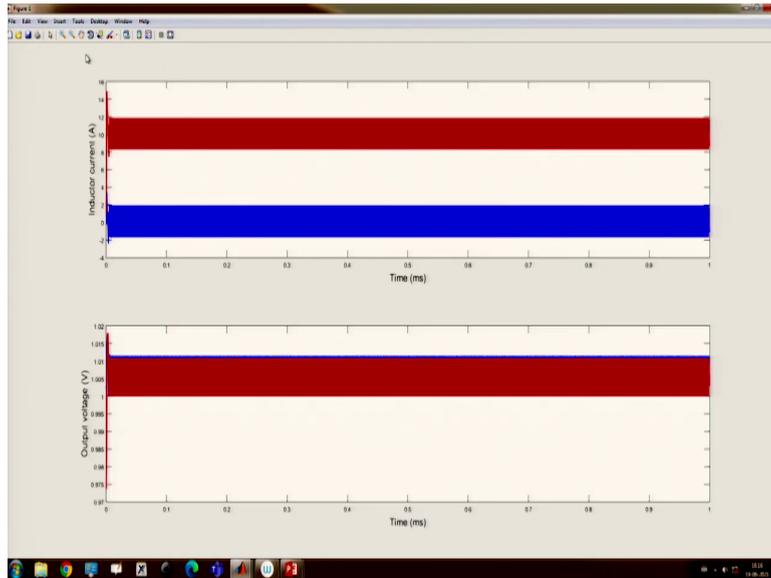
So, here what do we want to do? Ok.

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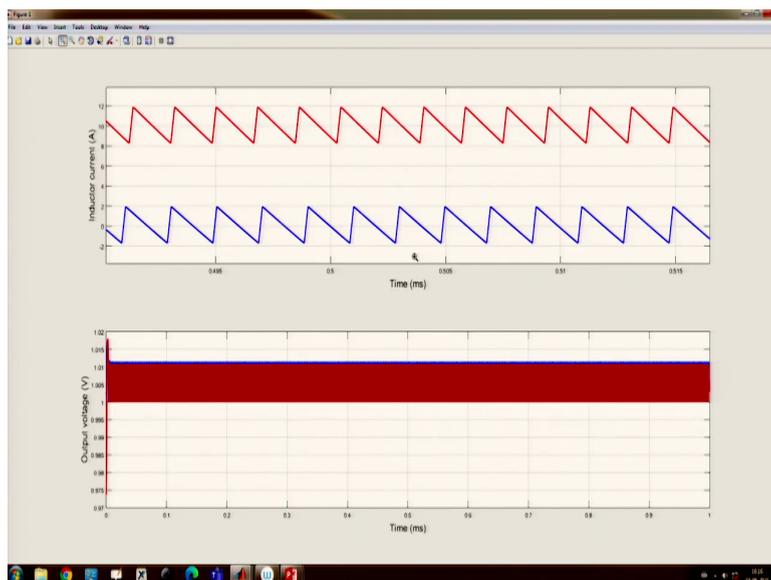
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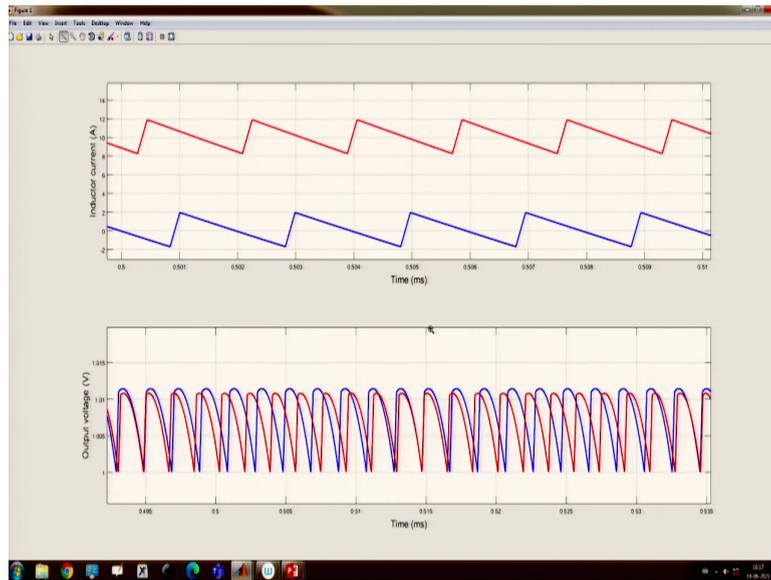
If I take a few cycles around 0.5 to 0.51, 0.5 to 0.51 ok.

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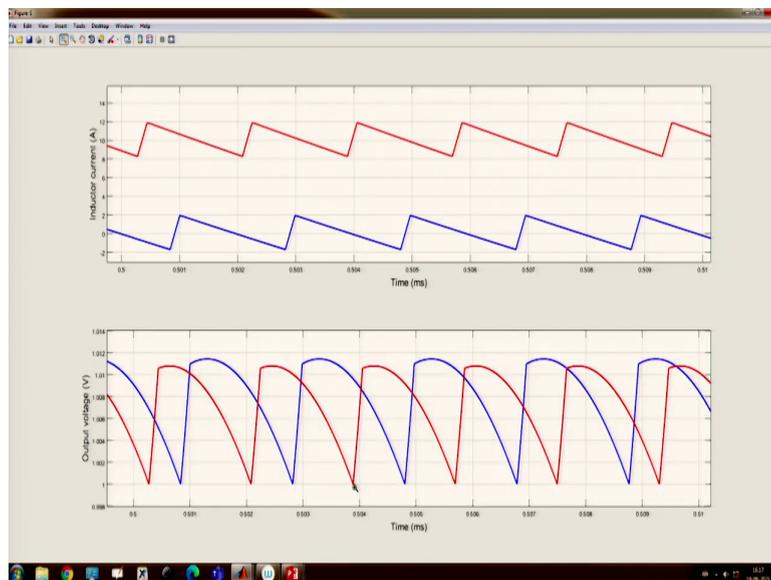
So, it if we take 0.5 to 0.51, what we will find that the time periods are more or less same there is a time shift. Time shift you can see, but the switching period if you take.

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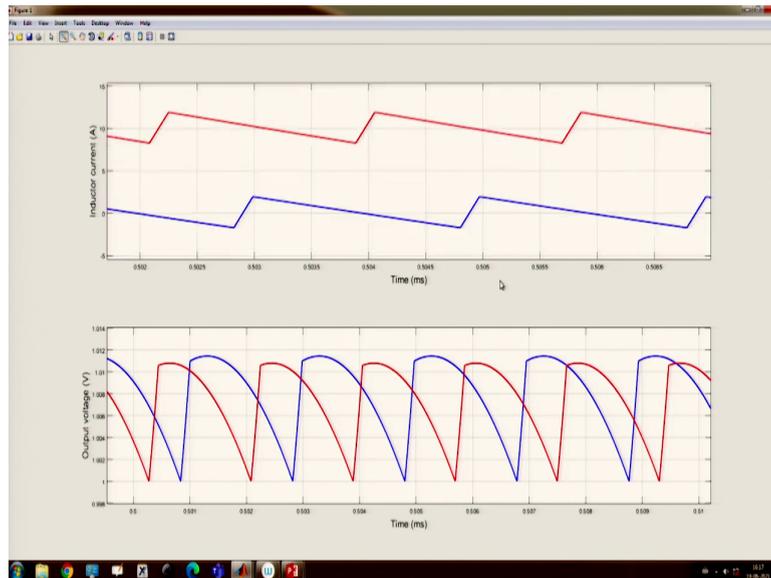
What is the switching period? For this case, it is close to 2 because 0.502 to 0.504. So, 2 milli 0.002 milliseconds; that means, 2 microseconds, in this case, it is slightly higher than or it is, almost.

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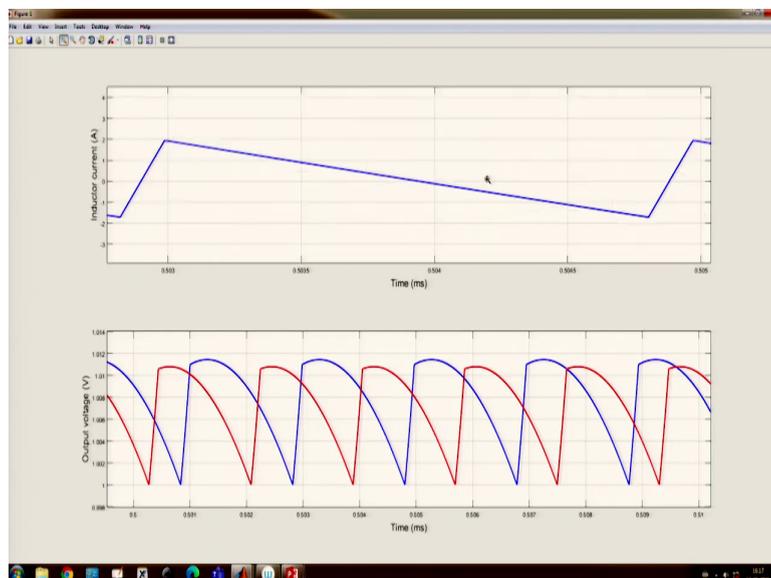
Again, if you take this cycle to this cycle it is again almost 2 microseconds.

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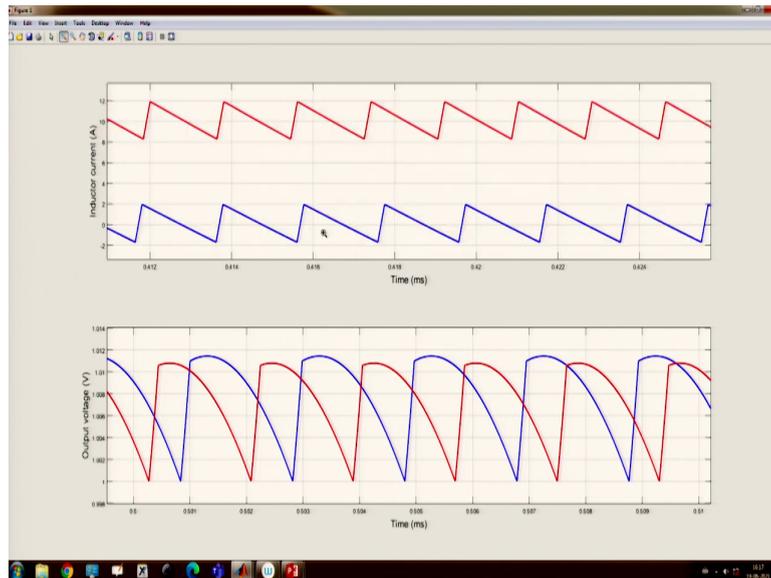
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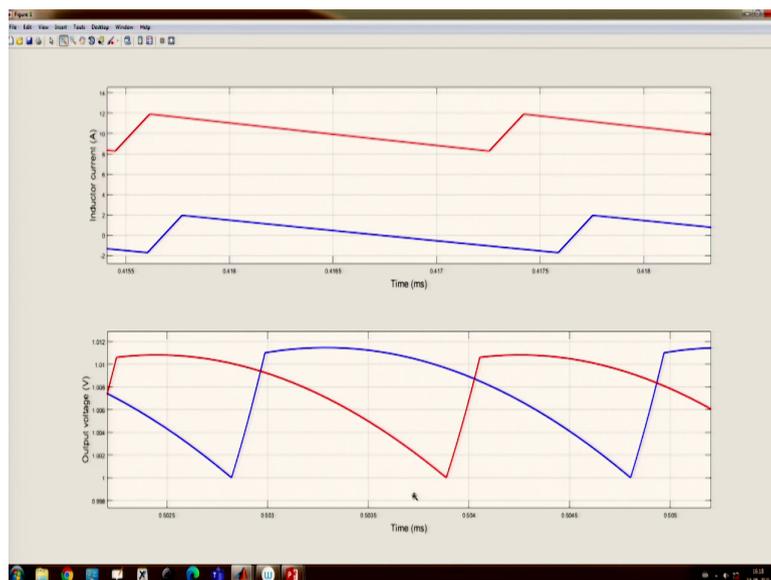
So, that there we are getting the switching frequency close to our desired 2 microsecond because it corresponds to 500 kilohertz, but there is a time shift. Because both are variable frequency operation, so any perturbation that will shift the time as well.

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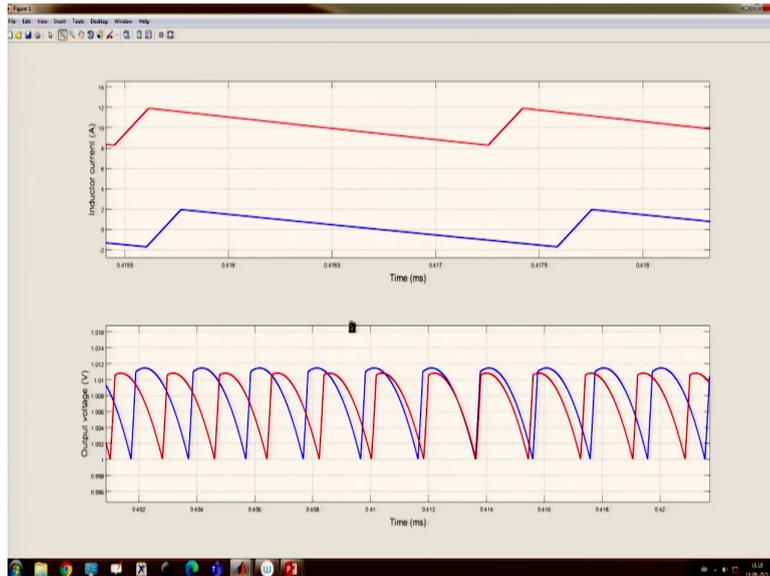
That means, we can nearly achieve the fixed switching frequency or desired switching frequency for because we set the on time based on V 0 V ref by V in ok alright. So, nearly constant I will not say exactly constant, but nearly constant ok. So, now coming to our that means two things we have seen. Now, we want to do transient simulation on what happened if V in is equal to. So, this part we are going to consider in another lecture where we will make a comparative transient performance.

So, for the time being, let us just make a transient simulation R equal to change in V in and change in V ref let us do the transient simulation.

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Now, first, what are we going to do? We want to make a load transient. So, let us keep this is for 1 ohm, what is the value of the resistance? So, we will set R changes from 10 to 0.05 and V ref is equal to 1 volt.

So, R changes from 10 ohm to 0.05 ok; that means, let us go for will take R 1 will take R 1 R 1 equal to how much from what to where it goes from 0.1 to sorry 10 ohms to 0.05 ok. 10 ohm and R 2 equal to 0.05. And how can we make load transient? Ok, let us go there are multiple way of doing transient, but in this case we are going to take this way.

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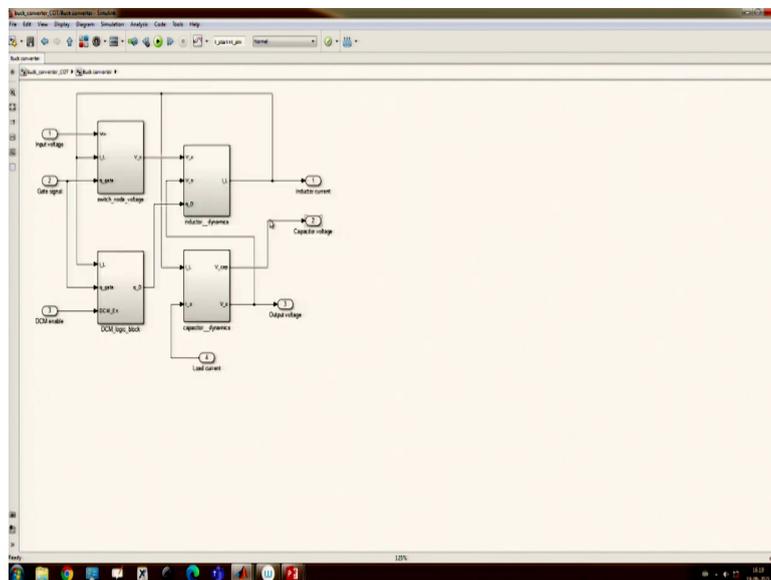
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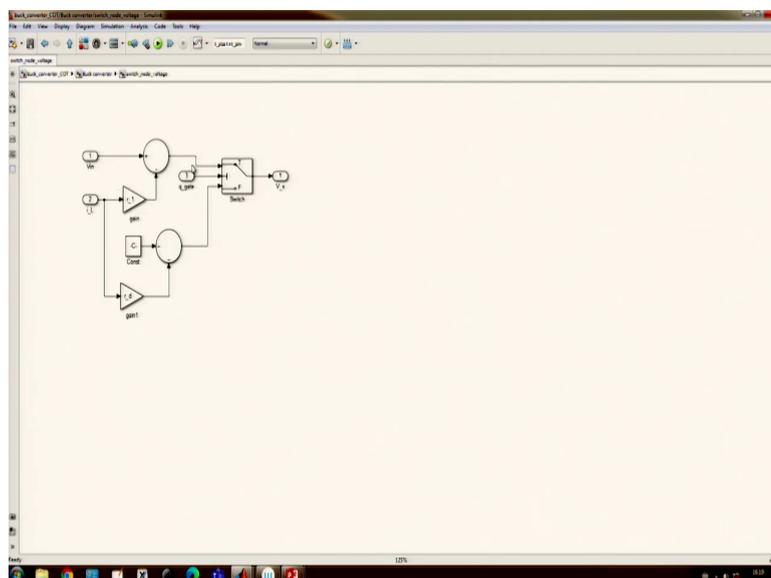
So, we will introduce a switch; that means, we already have some switch. So, we will take one of the switch ok.

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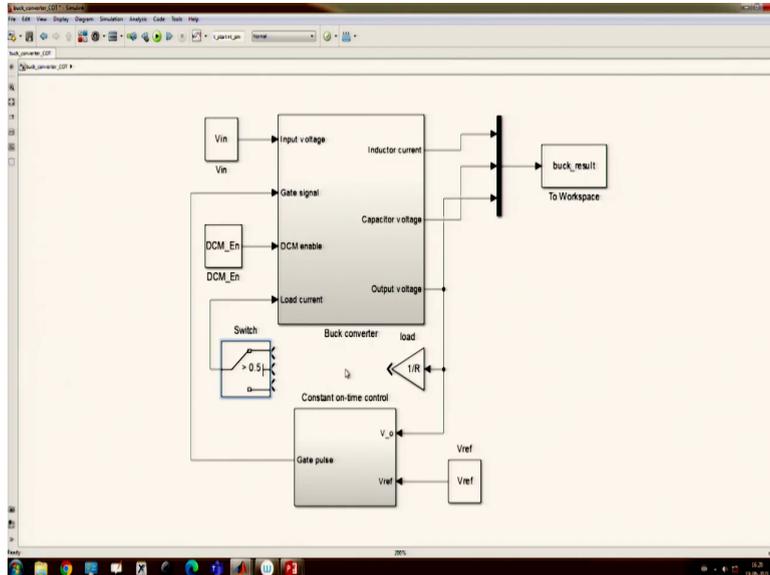
And we will introduce a switch here ok. So, this switch is my load resistance and let us go to the switch, so this is my load resistance.

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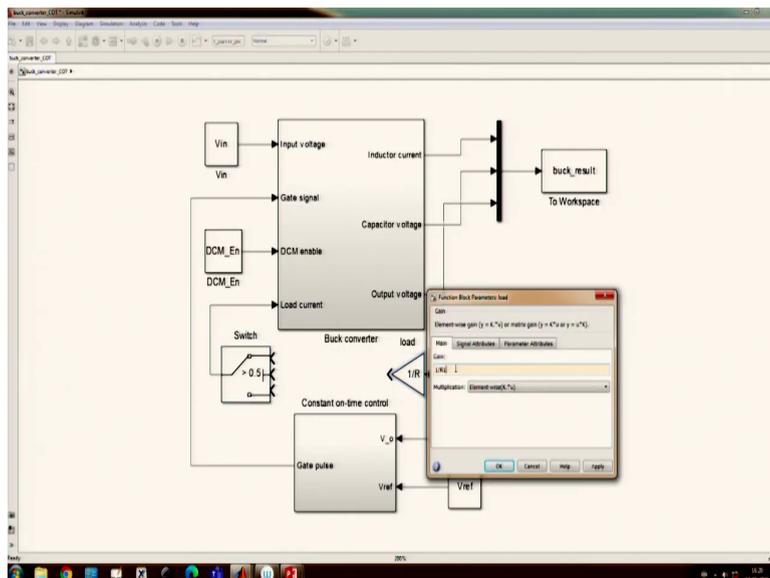
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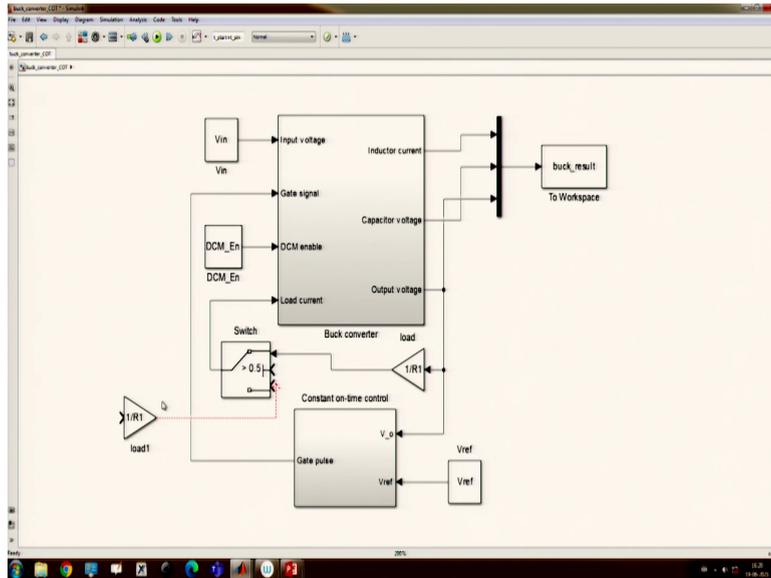
So, initially it will take R 1 that means, there are two load one is R 1 and the other one I want to take R 2, let us say this is my R 2.
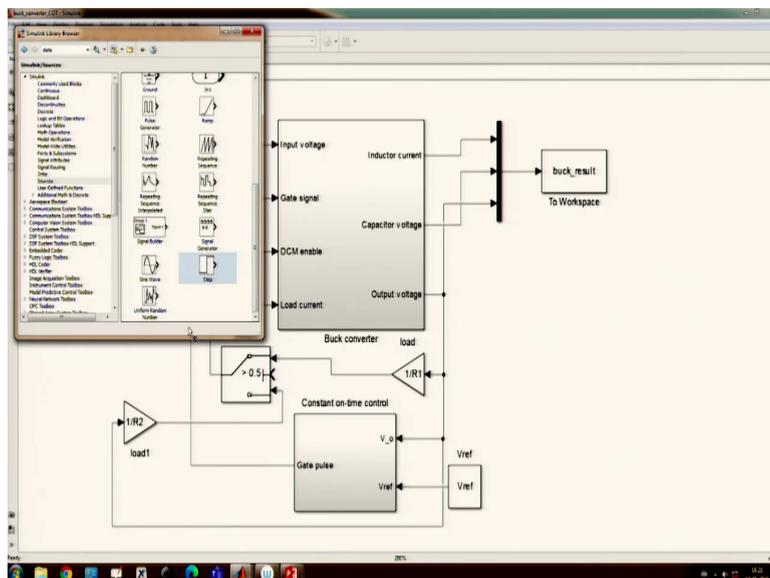
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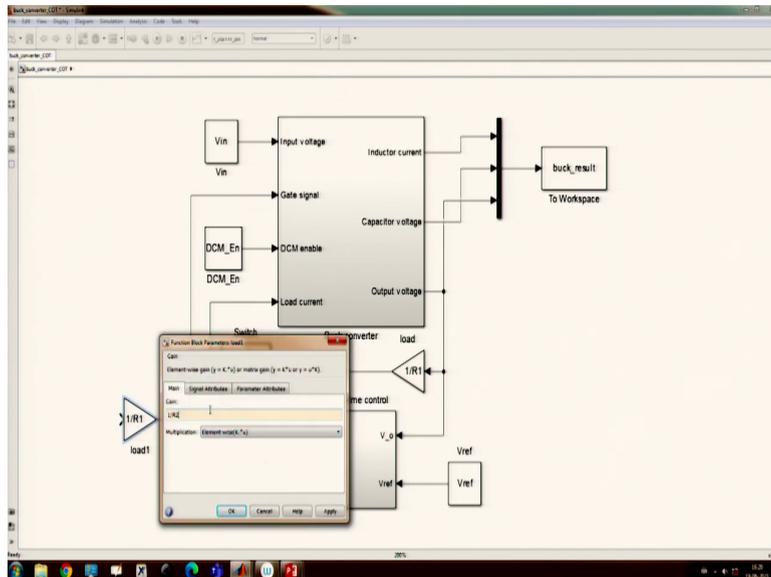
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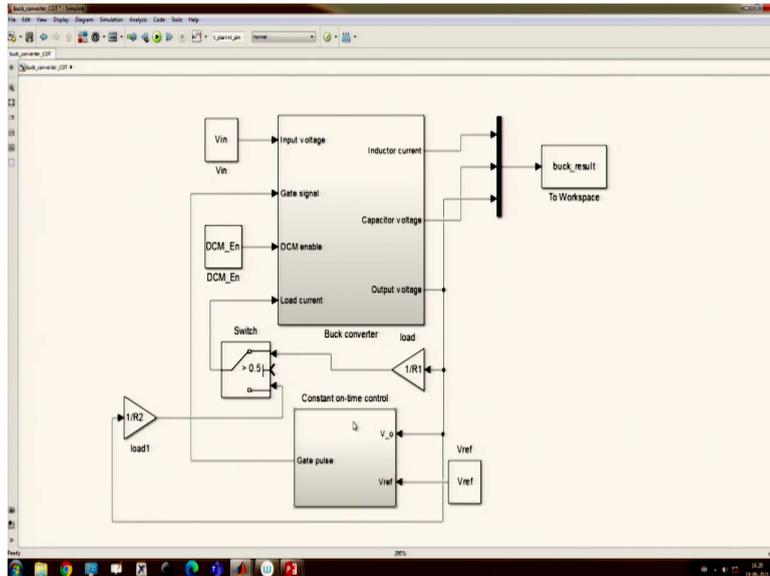
Because you should change R 2 ok that means, let us connect to this for load transient and this should be connected to the output voltage.

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And we need to provide a transient like sources yeah. So, we need to apply a step command; that means, where do you want the transient.

This is will be 1. So, at what time it is initially 0 it becomes high and what is the step time, at what time we are going to change? Let us say at 0.5 millisecond we are going to select transient ok.

Now, let us run this simulation. OK. So, you are running for 1 millisecond let us try.

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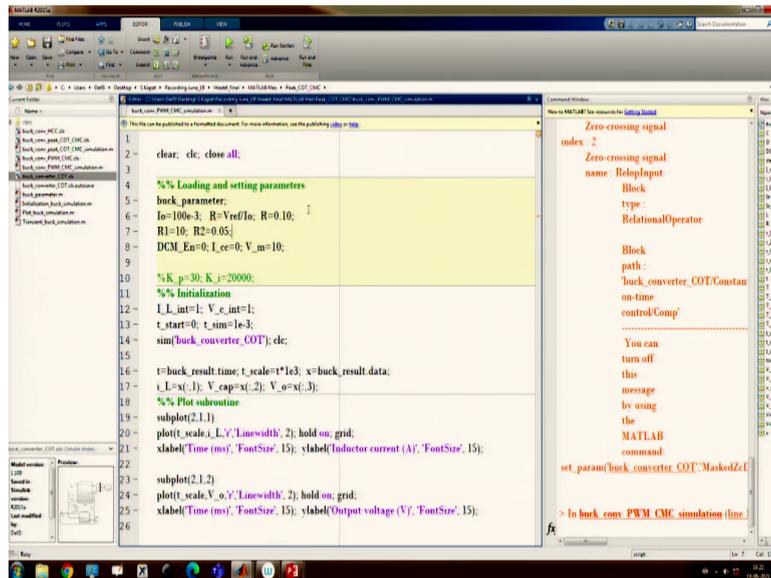
Yes.

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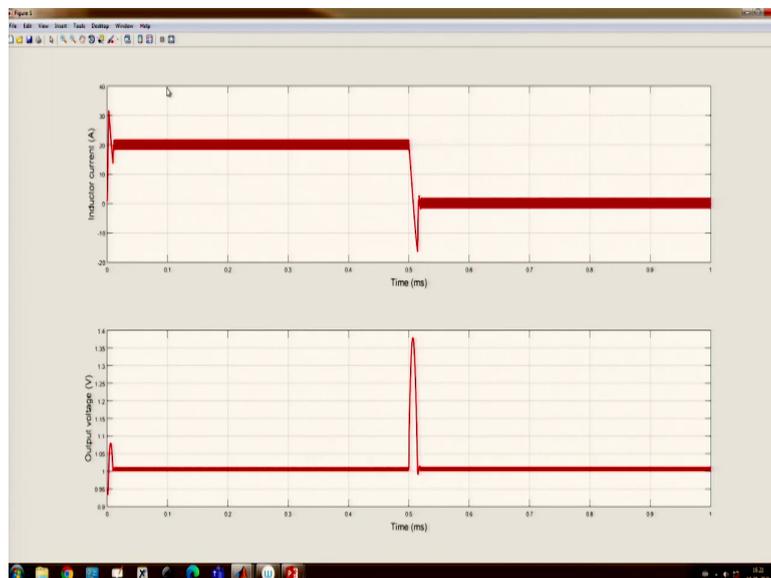
So, this is the load transient performance you can see initially we actually I think it changes from R 2 to R 1.
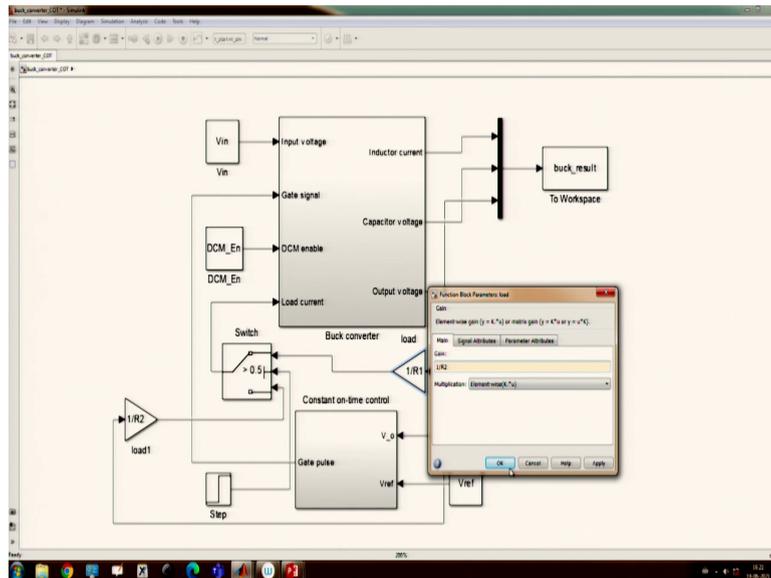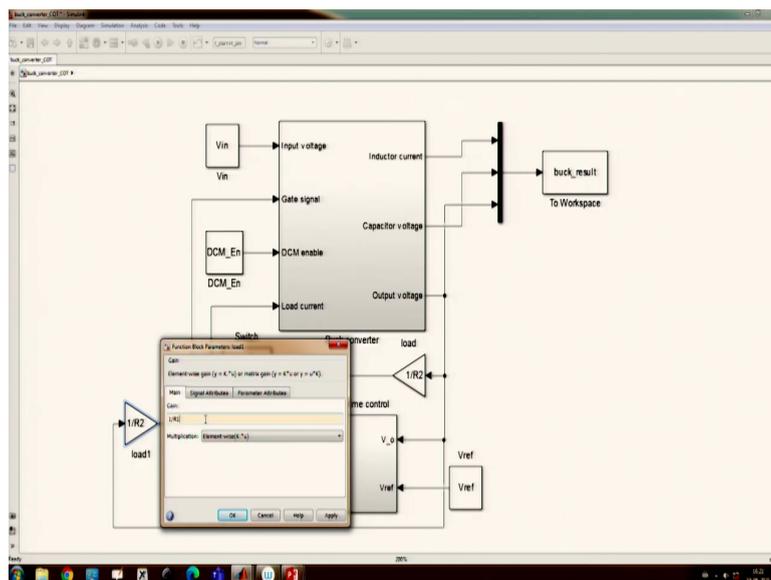
So, let us ok yeah it changes from. So, we have to take this as R 2 and this one as a R 1 ok yes.

So, this is a step-up load transient, how does it work?

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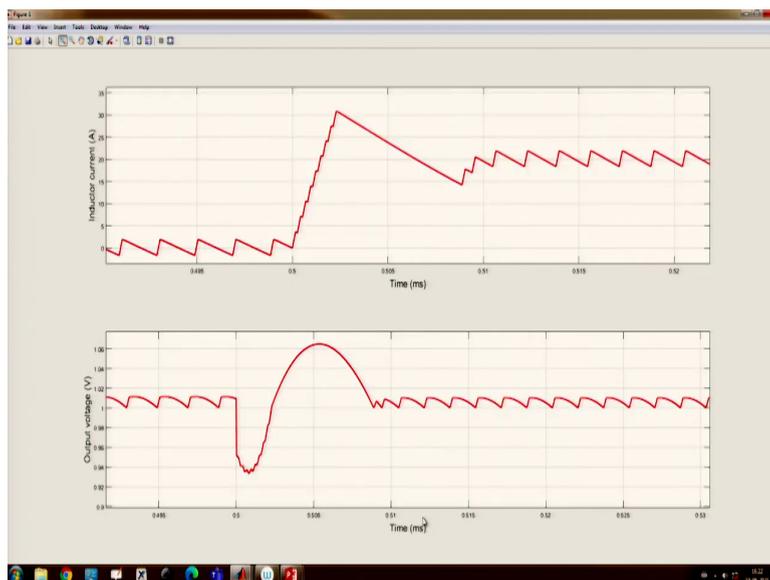
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So, you can see initially, when at this point we are applying a step up transient; that means, we are changing the load initially the load resistance were set to 10 ohm; that means, and it is in continuous conduction mode throughout. And this time we have turned on, we have enabled that you know there is a load transient.

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And during this time since there is a minimum off time you can see the minimum off time, this is the constant on time control that is why after certain duration it is getting turned off.

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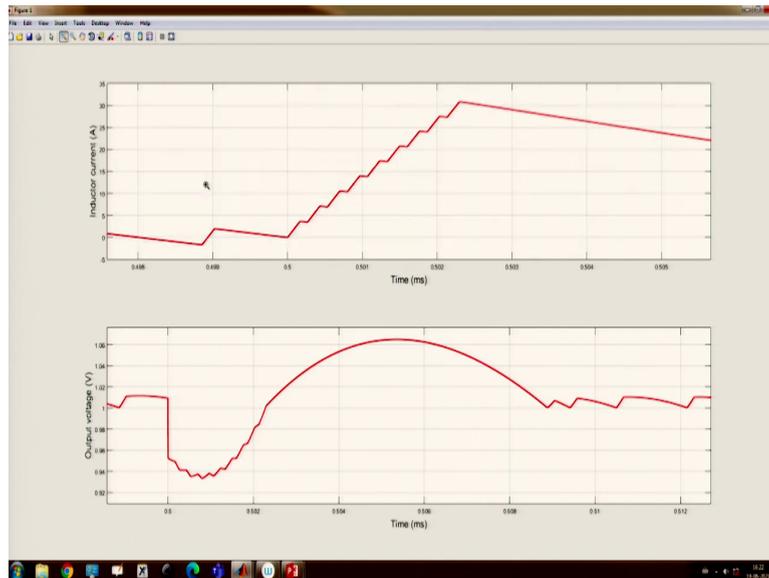
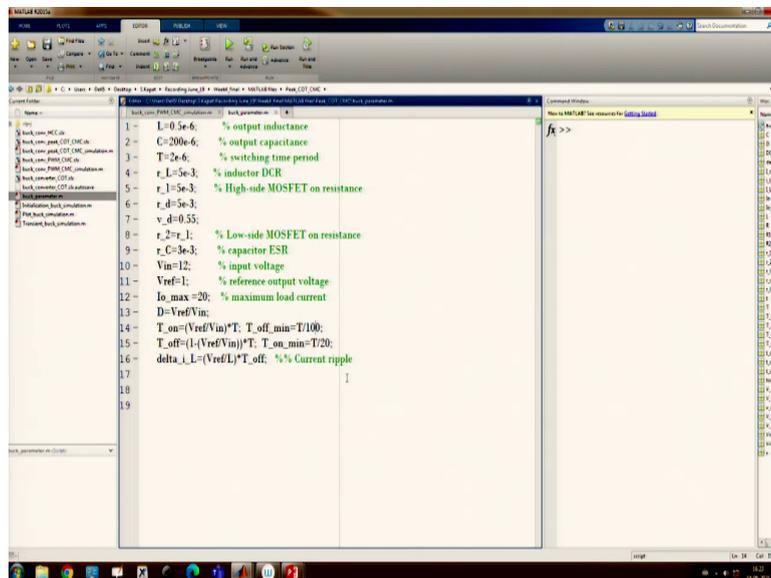And that is slowing down the process, ok. So, you can improve this transient performance by changing.

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So, we will retain the same value and let us run, we want to.
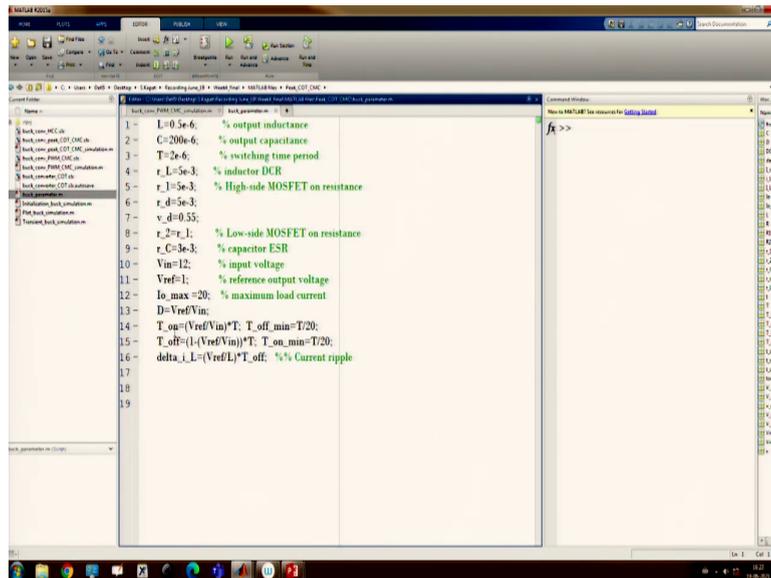
What will happen? Because here we set the minimum. I mean, here we have to set a minimum off time.

If I change to very small so, minimum off time to I chose T by 20; that means, it T equal to 2 microsecond. So, we are taking 200 nanosecond is my minimum off time, but if I now reduce to 20 nanosecond then we want to see what happened.
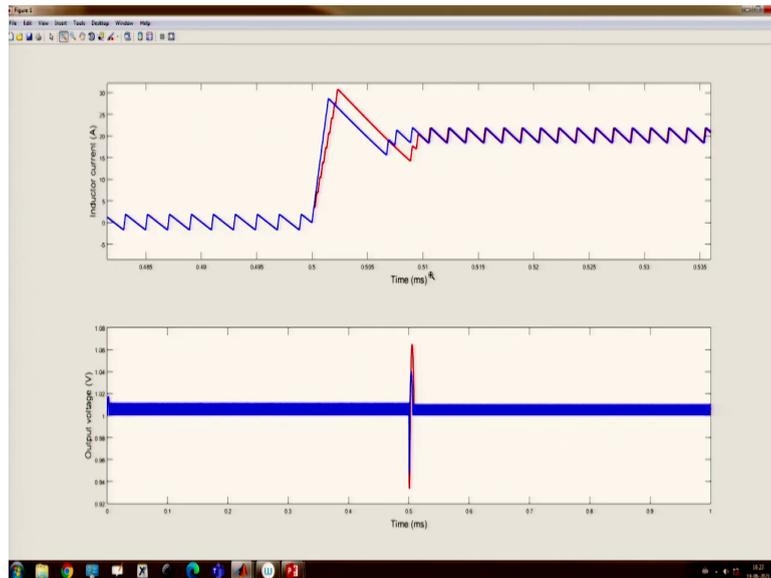
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So, we want to repeat the simulation and check what happened in the load transient response. It will overlap the 2 response will overlap ok.
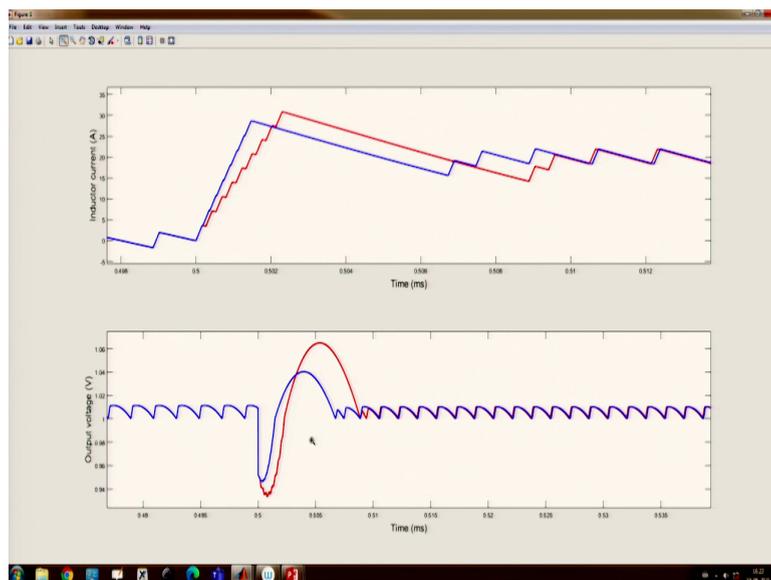
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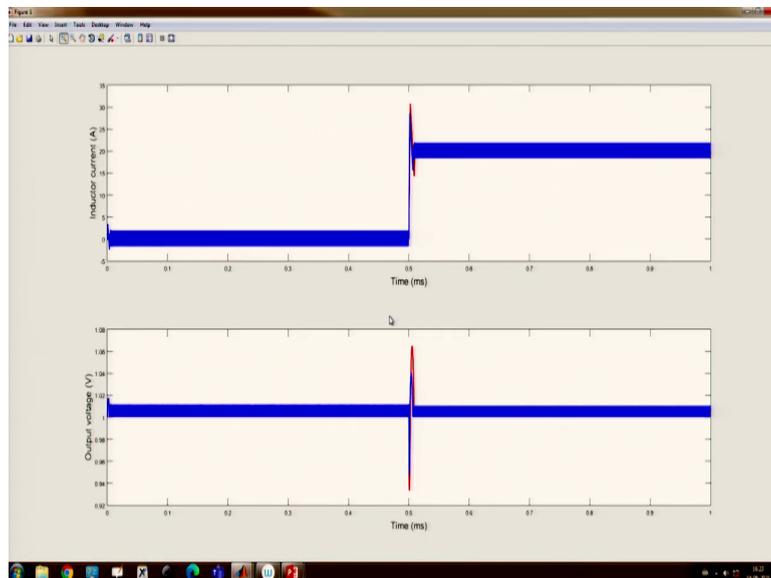
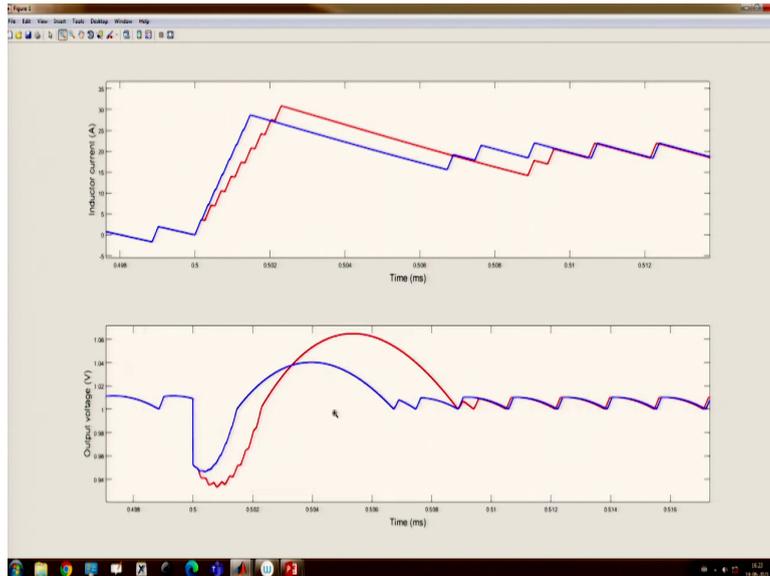(Refer Slide Time: 30:54)
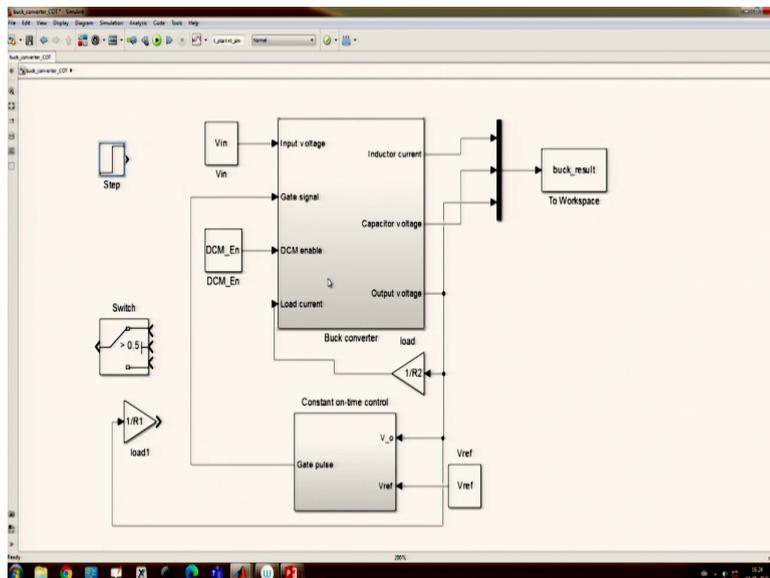

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So, some improvement we can see in the transient performance if we can reduce the off time.
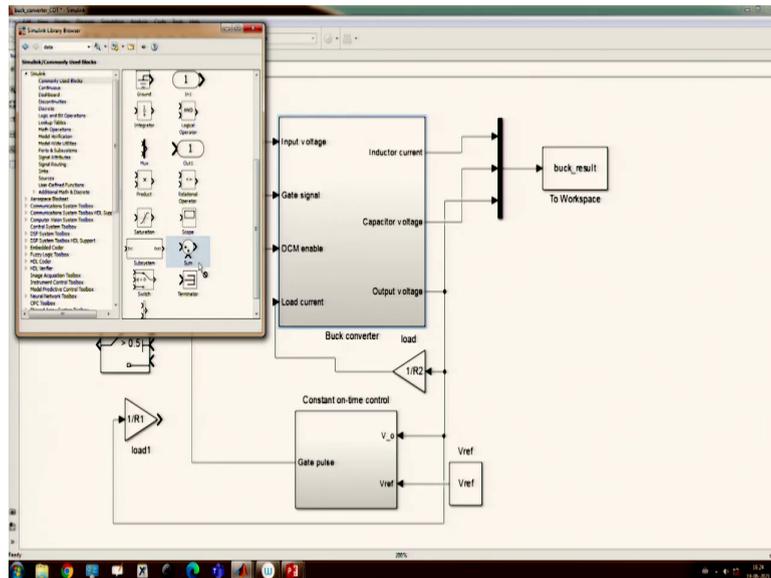
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But the transient response seems to be fast, but there is a significant overshoot and that we have to take care ok. So, this is a transient performance that we have to check. Similarly, we can make the supply transient; that means, how to make supply transient? So, we will keep load equal to 0.1 ohm and we will change V in from 12 to 8 volt, how to do that? We can do that.
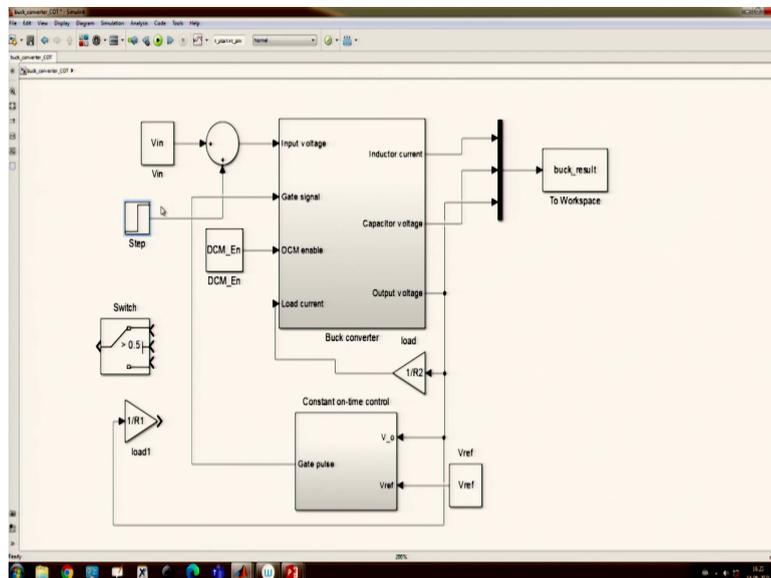
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So, if we again go there now we will fix will take directly from this R 1 ok or maybe we can take R 2. What is my R 2? So, we will take this gate signal far away ok.
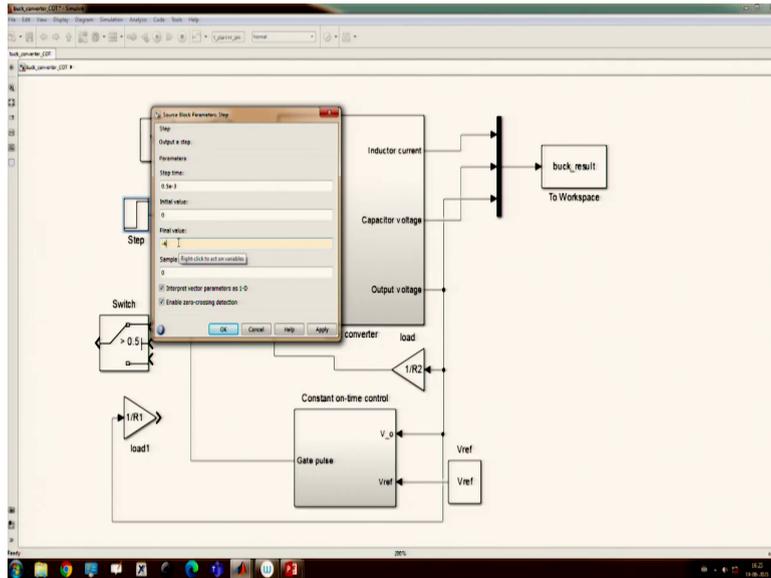
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Now, what are we going to do? We want to incorporate 1 summing block, which is summing block.
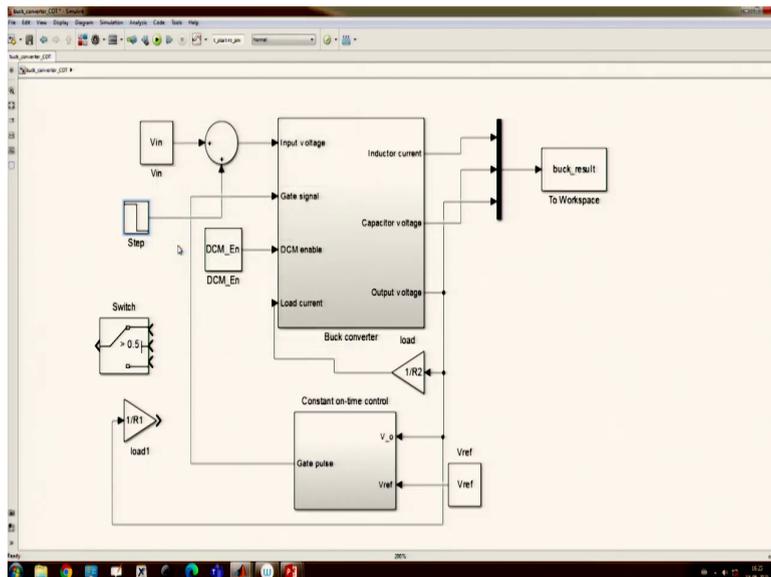
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And here we want to make a load supply transient. How to make it? That means, initially I will take this 12 volt is the input.
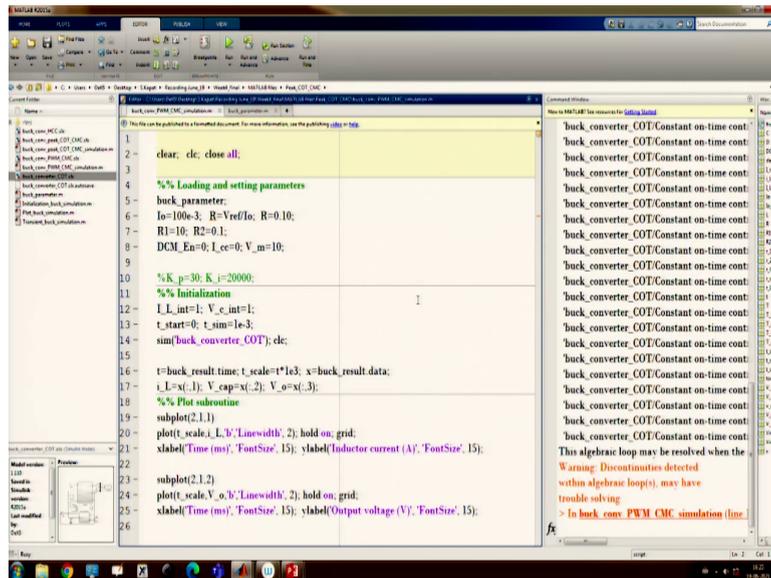
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Now here at 0.5 I will make minus let us say 4 volt.

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That means, supply changes from initially it was 12 volt and now we are subtracting by 4 so, it will be 8; 12 to 8 ok.
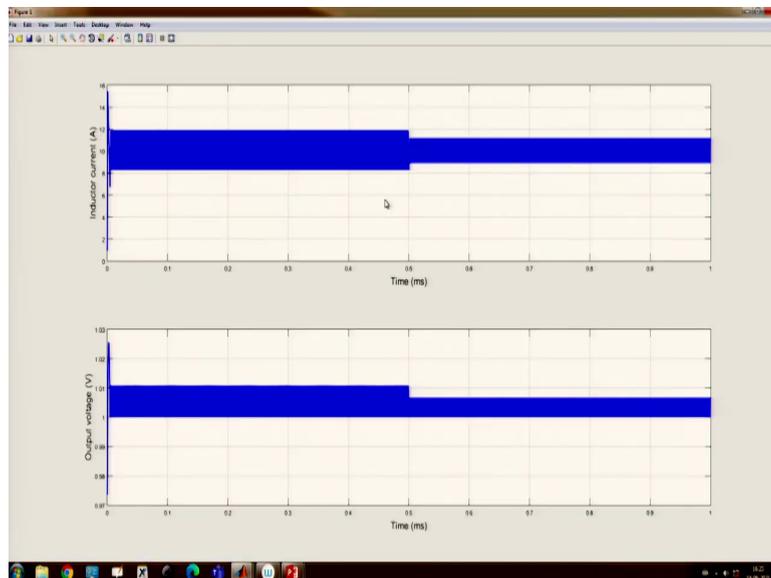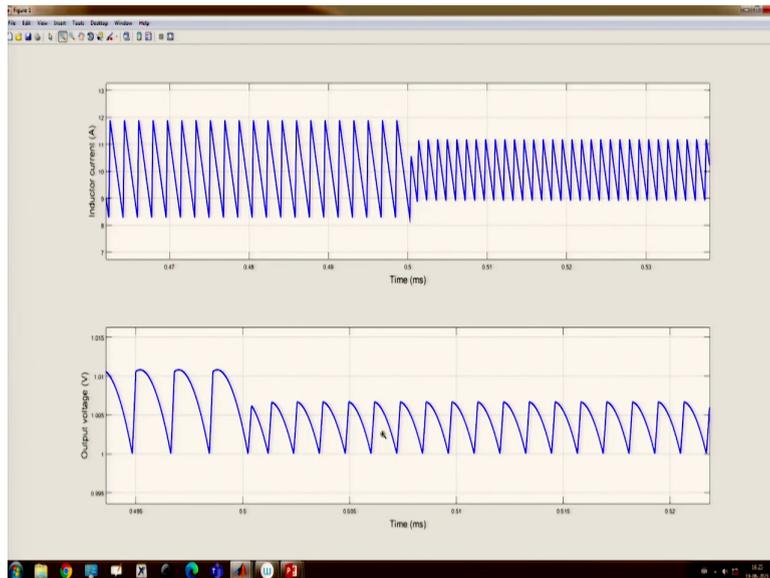
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And R 2 how much you are taking? R 2 we are taking R 2 0.01. Let us say is 0.1. Let us run now. We are making a supply transit and see what happens.
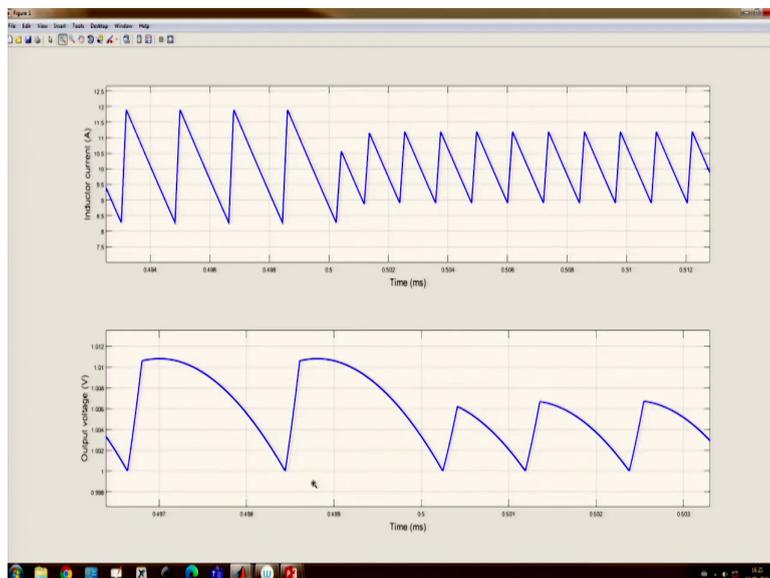
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So, if we make a supply transient, you will find the transient performance is really fast.

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But there is a change in switching frequency and also there is a change in output voltage ripple. So, this and we will see there is a drawback of the constant on time control. If we keep the on time constant, the voltage ripple can get significantly affected when there is a change in input voltage. But in case of changing load resistance, it was not a problem in continuous conduction mode. It will closely maintain the switching frequency, but it is not the case for the input voltage variation ok.
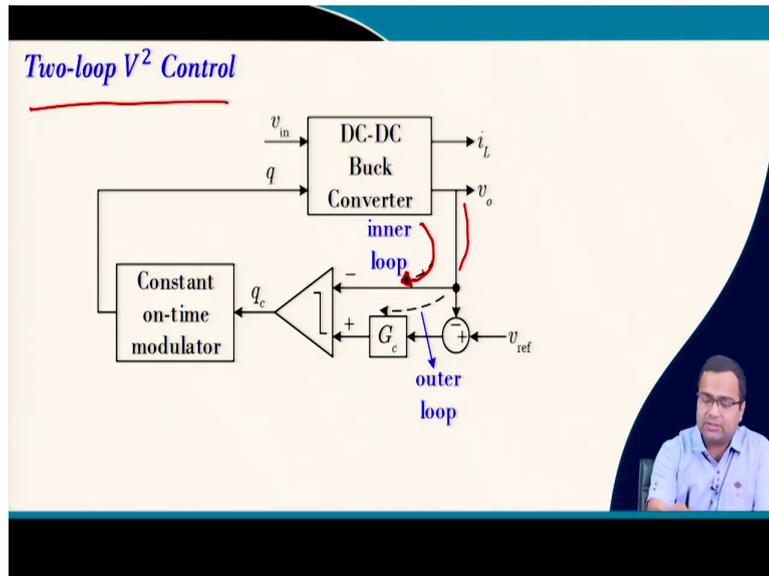
So, let us go; that means, we have discussed the steady state condition; we have discussed a transient condition for this constant on time control. Now another feedback control using constant on time modulator is called V square control, in which V square control two loop control.

There is one loop which directly takes the output voltage and the other loop it is an error voltage with compensator. So, this loop is the inner loop which takes the first dynamics of the voltage ripple and this loop is slower outer loop. So, this is also known as V square control.
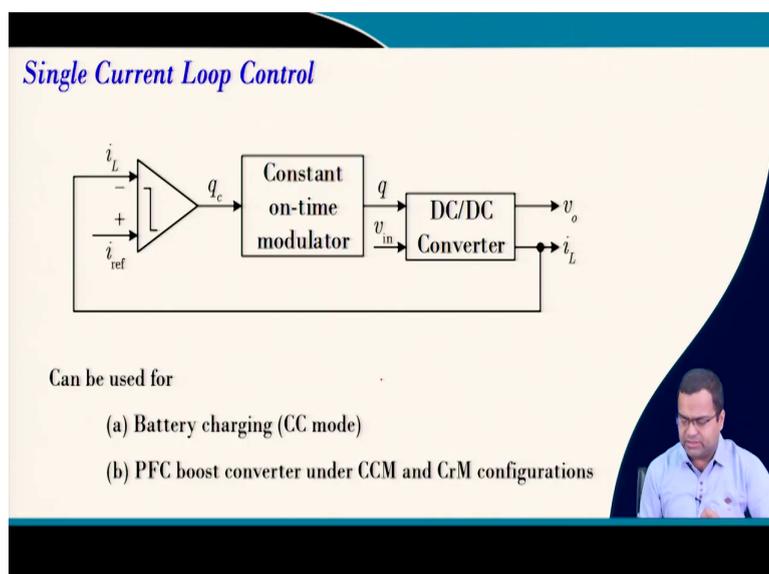
Now single loop current control, we talked about single loop voltage control, we can also talked about single loop current control, here the inductor current is directly compared to the reference current and then it goes to that constant on time modulator and we can control the current directly. It can be used for battery charging, for constant current mode and it is very much used for boost converter in terms of critical conduction mode in PFC like unity, you know for power factor correction like a boost converter.

And, if you use in a critical conduction mode, the constant on time modulator can perfectly track the current and you can achieve close unity power factor ok, but with the variable switching frequency.

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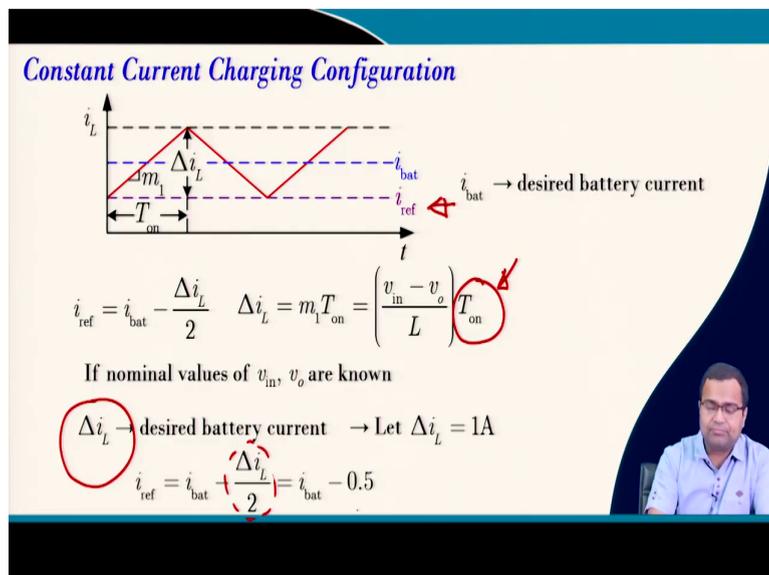
Similarly, constant current loop can be used for battery charging application, where if you take a boost converter or a buck converter, the reference current you know constant on time we control the valley current, it is known as valley current. And we will this will compare this result and the ripple current for buck converter. We know that v in minus v 0 by L.

And if we set for a given input output voltage, if we can set the right, if we can identify the right value of ripple current, or we can accordingly adjust the on time to get a desired current ripple. Then we can control the reference current by battery charger by setting a suitable delta i l by 2 a by selecting the on time correctly and we can track this is possible.

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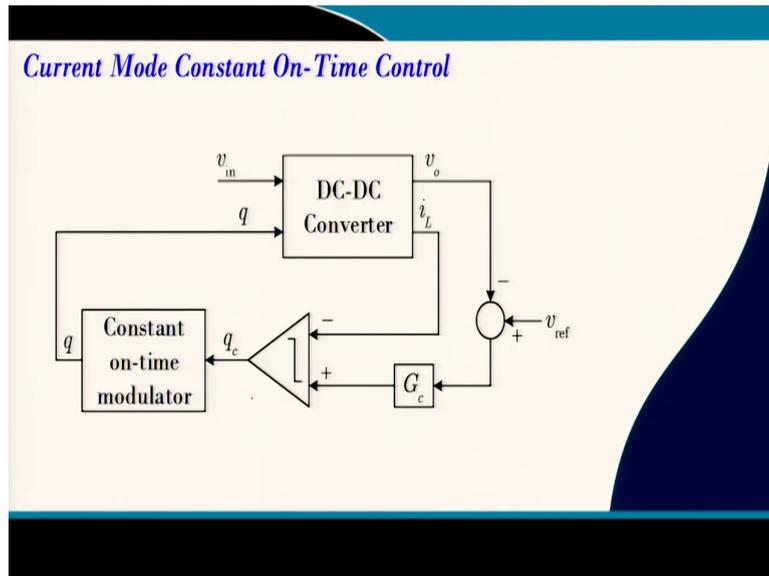
In case of constant on time current mode control ok, current mode on time control. So, let us go back and two loop control how does it look like in simulation ok. So, if I go back to our MATLAB file, now I want to run this model of constant on time control. We have simulated and we have also shown the waveform. Now we are talking about constant on time. Current mode control is also possible; that means, if you go to constant on time control yeah.
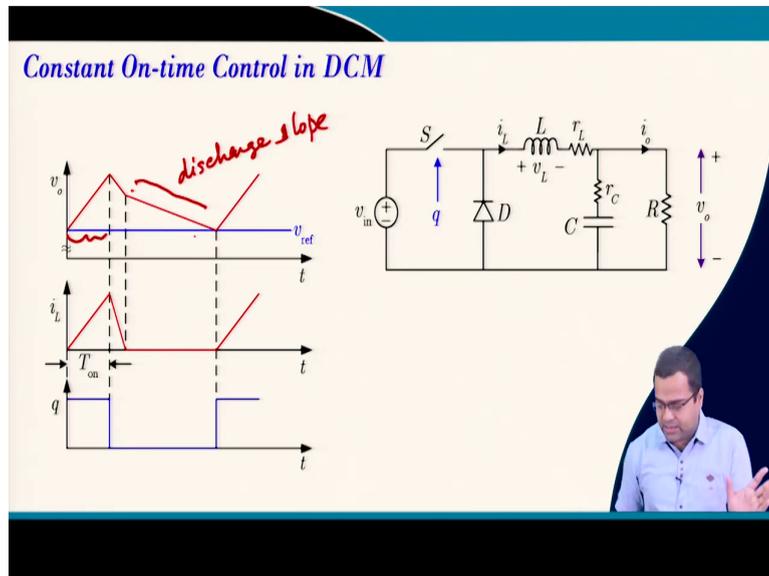
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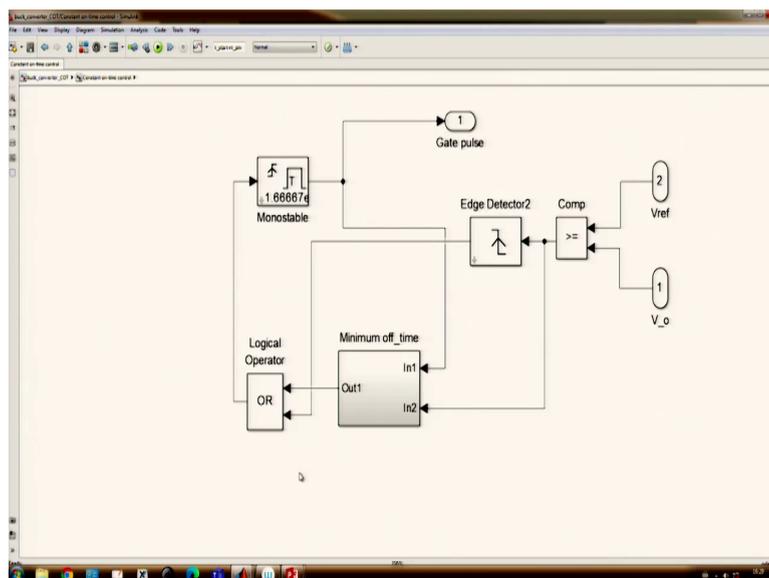
Here we can replace the current loop control by voltage. You know in voltage based control we can replace with the current based control also ok that is possible ok. And we will

compare this result in a different session where we will compare the performance of different control scheme.

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In discontinuous conduction mode, we have shown that constant on time control is frequently used in commercial product, why? Because we have seen the diagram; that means, in constant on time control, we saw if you fix the on time, if we keep the on time fix then the time period will vary based on the load current condition based on the rate of discharge of the output voltage. This is the slope, this is the discharge slope. And how does it vary?

Because during 0 inductor current, this will be purely dependent on the amount of load current. That means higher the load current, the rate of discharge faster, smaller the load current it will be slower. So, accordingly, the time period will be adjusted.

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And if you do DC, you know steady state analysis in discontinuous conduction mode and if you keep on deriving using the capacitor charge balance; that means, different charges shown here.

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And by calculating the capacitor charge balance, it can be shown their the switching frequency the effective time period or you know effective switching frequency under constant on time control. This is the derivation. For a given set of input voltage and output voltage, this quantity is constant if we do not change input output voltage. This quantity is also constant if we keep the on time constant, which indicates that the switching frequency is directly proportional to load current.

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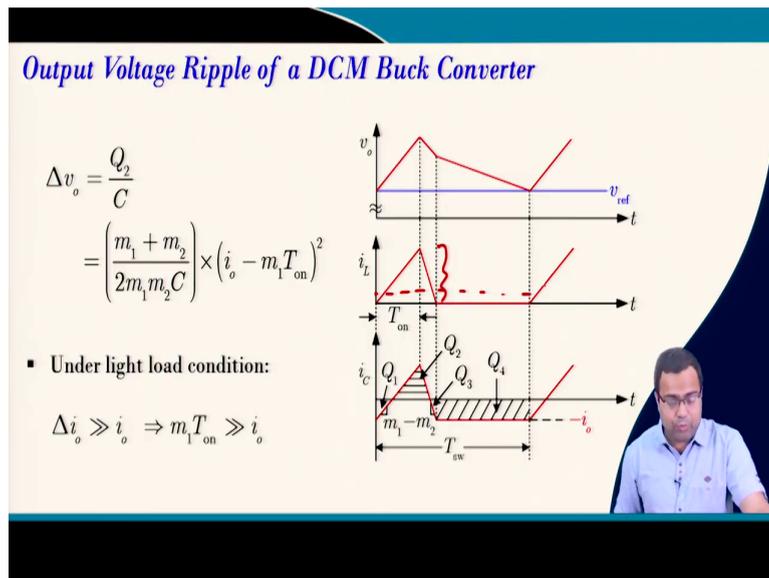That means, the switching frequency is directly proportional to load current because under given input output voltage condition this is constant, this is also constant. And this is very powerful for light load efficiency improvement and we have a session dedicated to this and I will discuss more about this discontinuous conduction mode, but this is today I am just going to touch upon how the output voltage ripple changes.

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Now so, it is we identified the switching frequency under discontinuous conduction mode is proportional to load current under constant on time control. What will happen if, what will happen with their output? That means, if the load current changes and if we keep on time constant how is it going to affect the output voltage? So, if we take the output voltage and under light load condition, the current ripple may be much higher than the average inductor current.

And if we put this assumption, then it can be shown that the output voltage ripple can be approximated by this expression, which means if we keep this quantity constant. That means, for a given input voltage output voltage given inductor and capacitor and given on time, the output voltage becomes more or less constant; that means, for load current changes, the output voltage not going to get affected significantly very small ok.
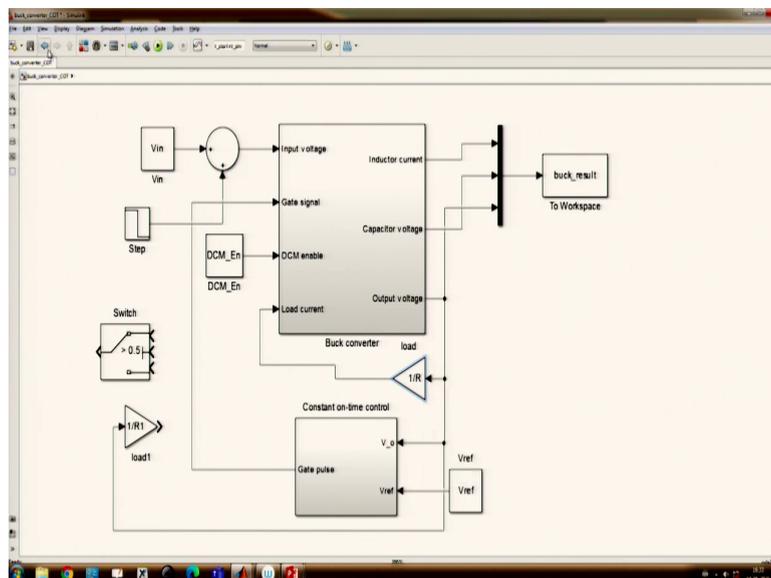
But; that means, let us take a simulation. Let us go to our MATLAB model and check our simulation case study ok. So, we are talking about light load condition.
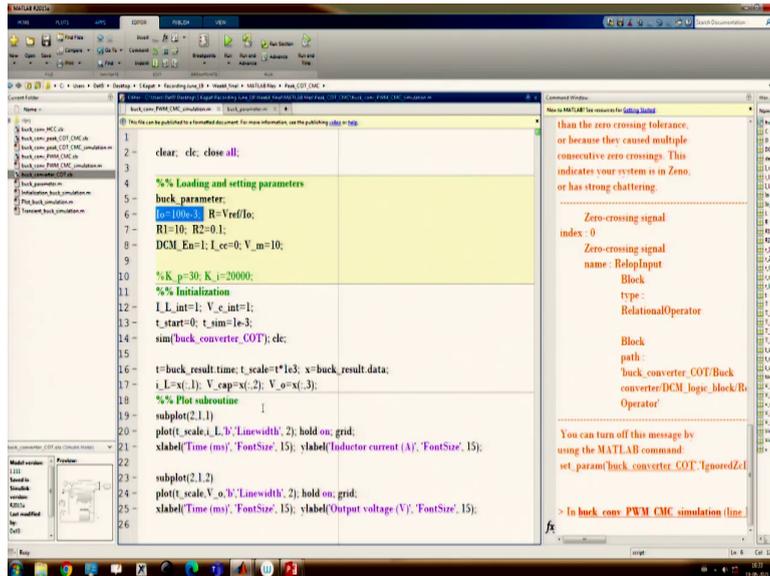
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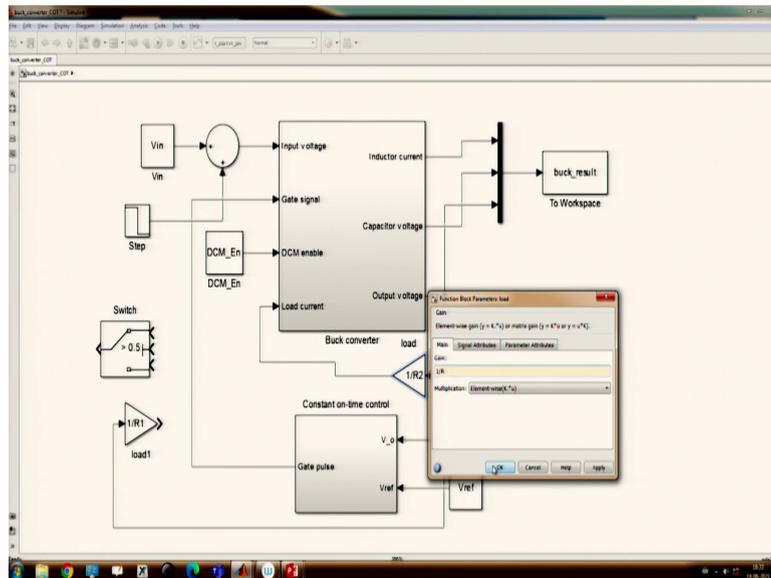
So, this is where we are taking from let us say R 1.
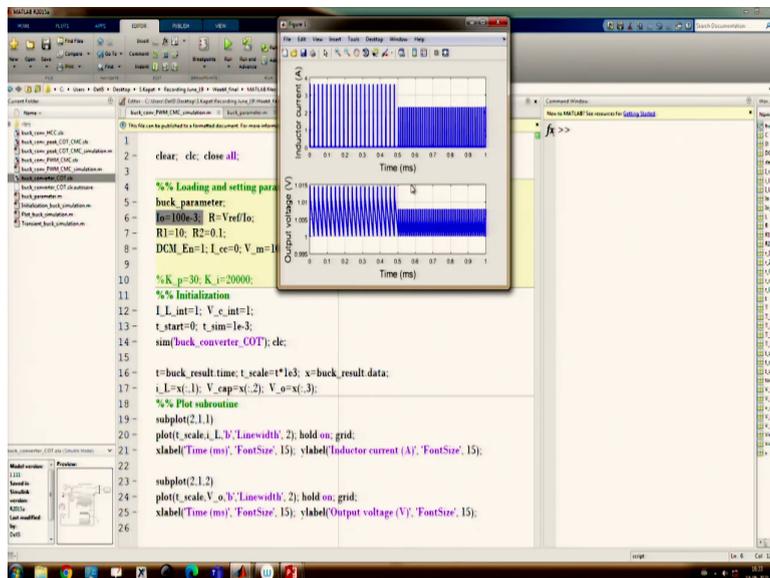
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Now what are we going to do? So, here we want to run in discontinuous conduction mode.
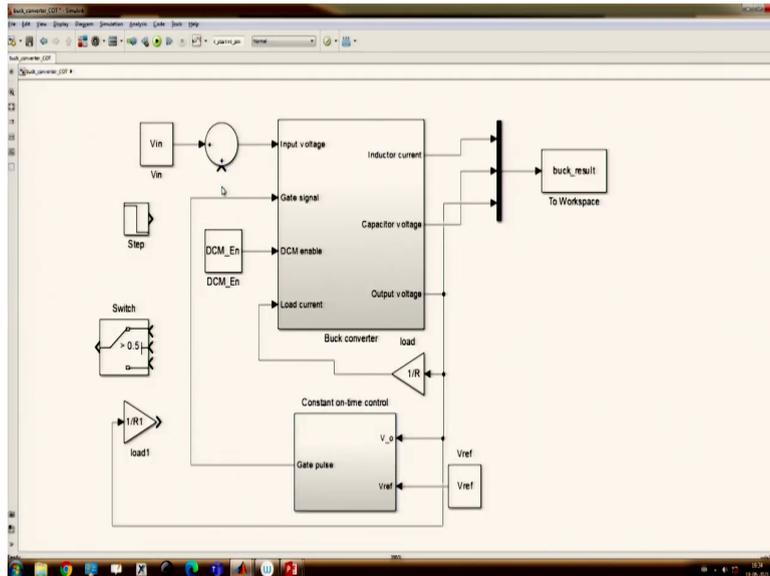
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So, you want to make DCM enable to be 1 and load resistance let us take ok. So, we will take instable load resistance and let us take two conditions: one is 100 milliampere current ok and let us run it and it is used for blue colour trace.
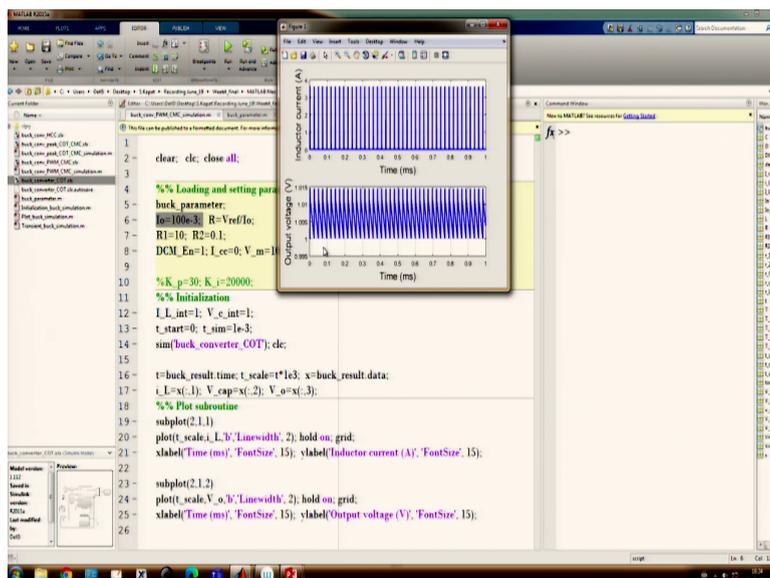
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And now so, here we are making input voltage changes.

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So, let us do not change it we are not changing any input voltage transient.
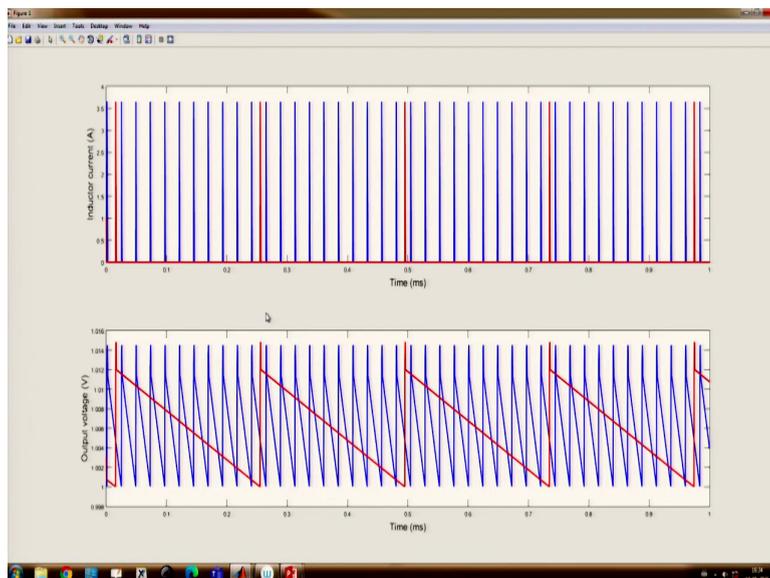
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So, I want to show you for 12 volt input this is a steady state condition.
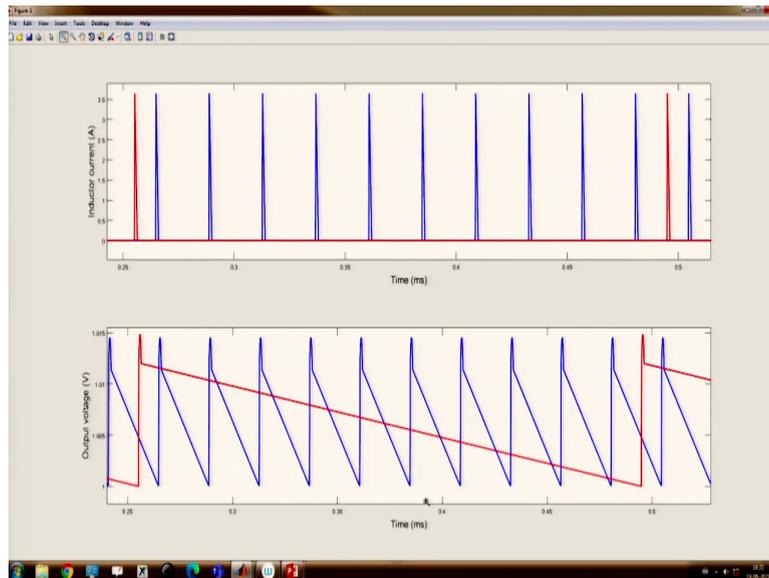
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Now, we want to go to 10 milli ampere current and we want to use a red trace and show what we want to see how does it change ok.

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Now ok, so you see the red and blue.

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So, our red is a 10 milliampere and blue is the 100 milliampere. So, in between you can see 1 2 3 4 5 6 7 8 9 10 so; that means, as I said the switching frequency is proportional to load current.

If the load current is decreased by 10 times, the switching frequency is decreased by 10 times and the time period is increased by 10 times and this exactly happened. Because you see in between 2 red waveform, periodic waveform that there are 10 such blue colour waveform so; that means, a 10 time fast higher switching frequency for higher load current for light load current it is.

So, we can prove that this actually changes the load current is switching frequencies proportional to load current. This is proved. Another interesting fact that we have just now we have seen that output voltage ripple is almost remain constant, output voltage ripple for both the cases.

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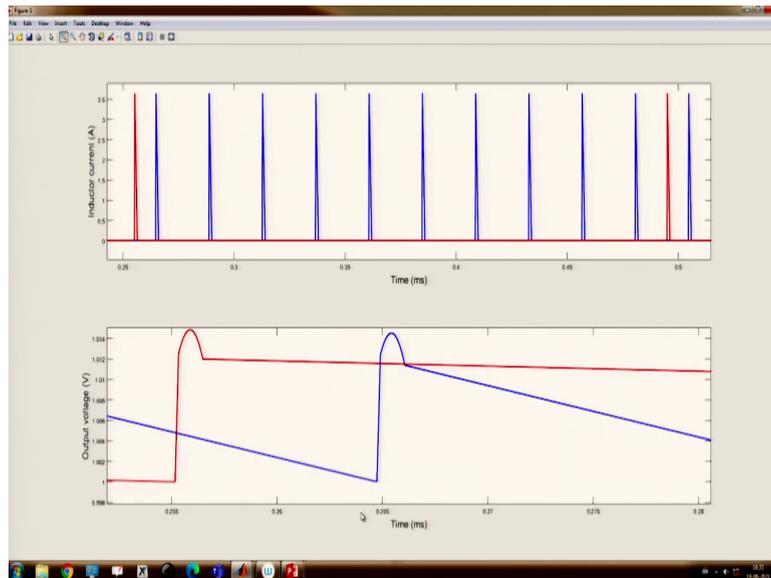
If you take output voltage is ripple, they are more or less and constant; that means, under constant on time control for varying load current in the DCM, the voltage ripple does not get affected. I mean significantly effect very minor changes. So, these are very good technique. Let me see. We can select on time to keep it within the band ok.

But it also has a problem when there is a change in input voltage, because you see this expression shows when there is a change in input voltage and both the terms are there in the numerator. So, it can drastically increase the in the output voltage ripple and can deviate for high input voltage can deviate the voltage travel limit. So, we need to do something adaptation in the on time ok.

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The same thing can be proved in boost converter and if we draw the capacitor current waveform and that you can check by yourself; that means, all the Q 1, Q 2, Q 3, Q 4 can be derived from this capacitor charge balance.

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And using the charge balance principle, you will arrive the same expression what we derive here. also f s w is proportional to i 0 for given input output voltage and given on time under constant on time control, ok.

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Voltage Ripple in a DCM Boost Converter

$$\Delta v_o = \frac{Q_2}{C} = \frac{\left(m_1 T_{on} - i_o\right)}{2m_c C}$$

$$\Delta v_o = \frac{\left(\Delta i_L - i_o\right)^2}{2m_c C}$$

Under high load conditions, $\Delta i_L \gg i_o$

$$\Delta v_o \approx \frac{T_{on}^2}{2LC} \times \frac{V_{in}^2}{\left(V_o - V_{in}\right)}$$

And for boost converter also if you see the load current, output voltage ripple it is the same principle as the buck converter only when input output voltage is remain constant that voltage ripple will be almost insensitive to load current variation ok.

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Adaptive On-Time Control in a Buck Converter
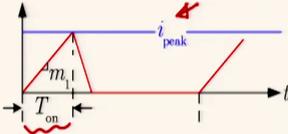
- Peak current based approach

$$\Delta v_o \approx \frac{T_{on}^2}{2LC} \times \frac{\left(V_{in} - V_o\right)V_{in}}{V_o}$$

$$T_{on} = \left(\frac{i_{peak}}{m_1}\right) \quad m_1 = \left(\frac{V_{in} - V_o}{L}\right)$$

Substituting T_{on} in Δv_o

$$\Delta v_o = \frac{Li_{peak}^2}{2V_o C} \times \frac{V_{in}}{\left(V_{in} - V_o\right)}$$

If $V_{in} \gg V_o$

$$\Delta v_o \approx \frac{Li_{peak}^2}{2V_o C}$$

12 V i/p
1 V o/p

Other adaptive on-time methods !!   PFM Control

And the adaptive one time so; that means, what will happen if there is a change in input voltage? Ok, now we are talking about two input voltage conditions.
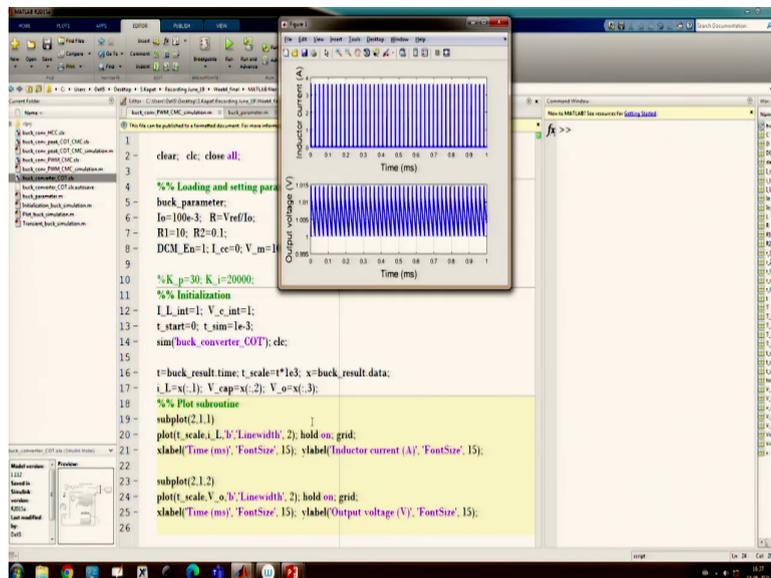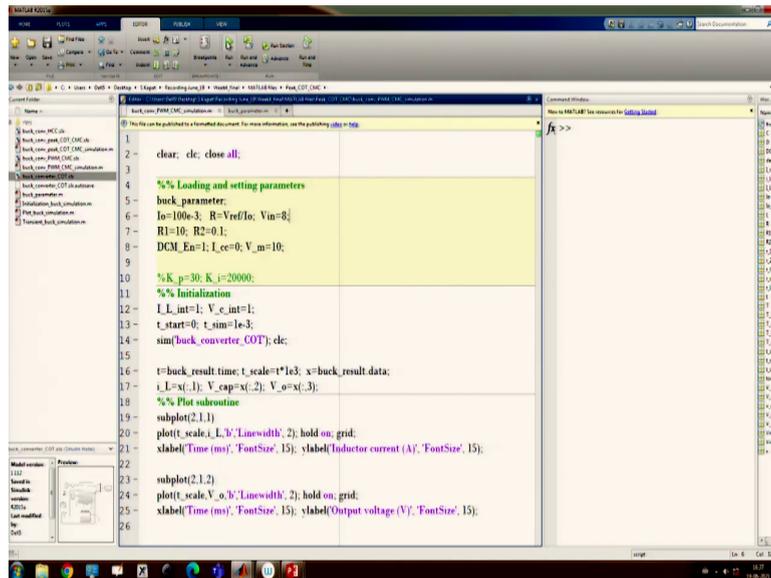
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Let us first stop this. Now, in one case, let us say it is under 100 milli ampere ok. And this case, we are talking the input voltage is 12 volt. It is already 12 volt. So, there is no problem.

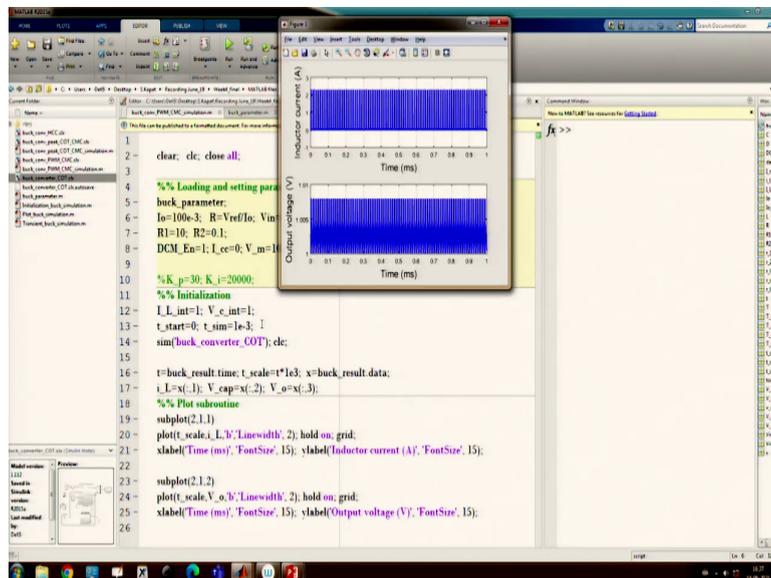(Refer Slide Time: 44:49)

The blue colour.

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Now we want to make a changes input voltage to 8 volt ok or maybe you know initially let us take 8 volt, 8 volt is our input.
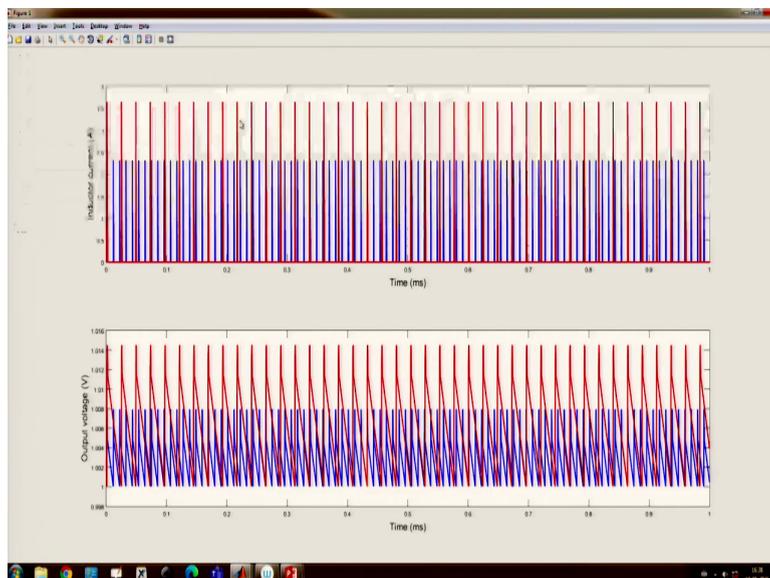
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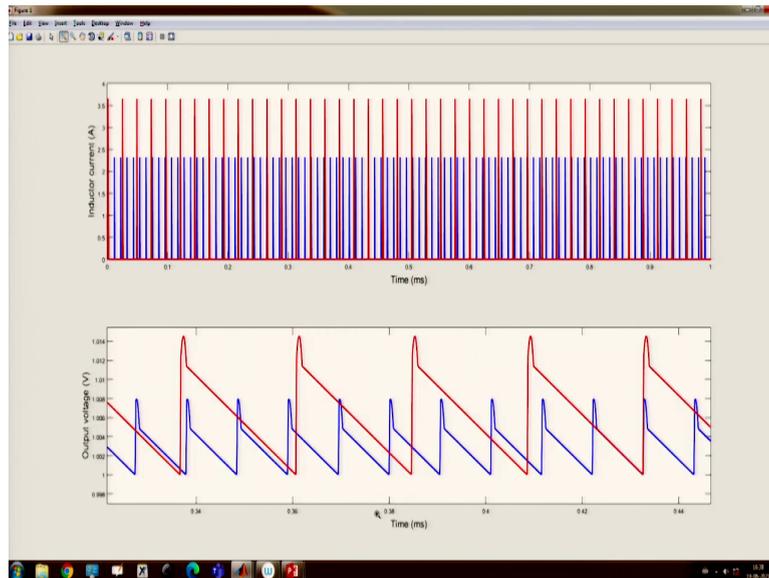
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Now we are making input voltage 12 volt and we are using a red trace for 12 volt and run it.

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What you will find that in 12 volt input the not only the time period has changed.

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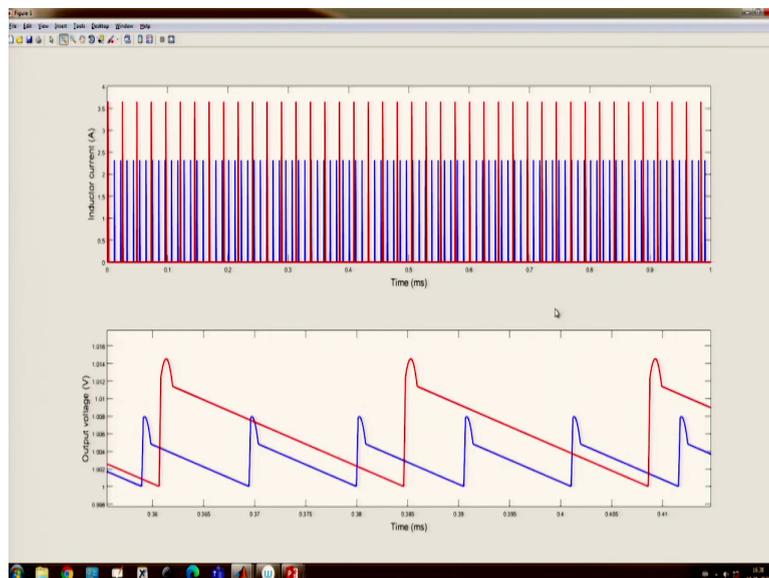
But it has significantly increased the output voltage ripple and it can go beyond the tolerable limit. So, we need to do some sort of adaptation. So, this is called adaptive on time control. How do you do that? Instead of using a constant on time through a timer circuit we can generate this on time by keeping a fixed current reference i p. And if I do that, then this is our original expression and what is the if we keep peek current then the on time can be calculated by peek current by the slope.

And if you substitute for a buck converter, we will get that delta v 0 is this and if the input voltage since we are talking about 12 volt input and 1 volt output. So, input is much higher than output. So, then this expression will be almost insensitive to input voltage change. That means, we will discuss in under in the context of light load control. So, if we keep a current based constant on time or PFM control, it is also known as adaptive on time or it is also known as PFM pulse frequency PFM control, where the output voltage ripple.

Because under fixed input voltage, the on time remains same, because this expression none of these quantities are changing. So, then it retained the linear variation with the load current that property is retained. Under variation in input voltage, it retained the ripple information that may ripple constant. So, this is used in many commercial products and we will discuss other adaptation methods.

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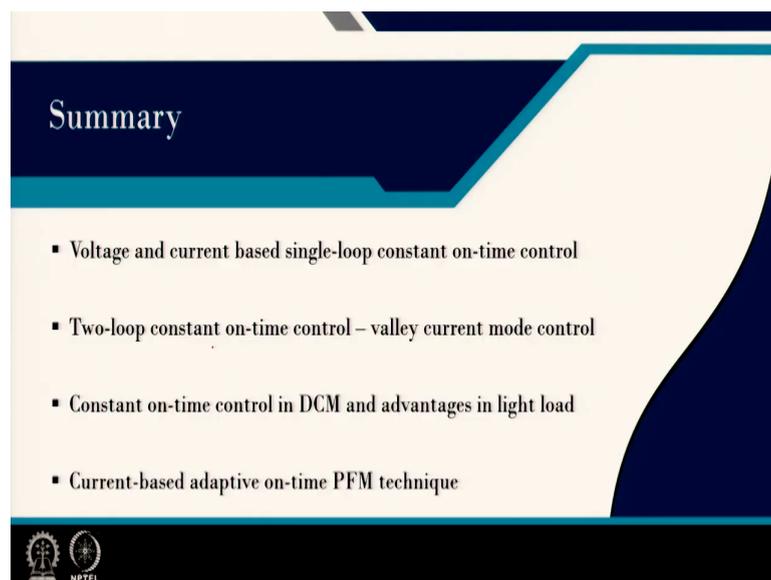
So, that mean voltage and current based single loop constant on time controls are discussed, two loop constant on time control, which is a valley current mode control, are discussed. Constant on time control discontinuous conduction mode and its advantages in light load are discussed and the current base adaptive on time PFM technique was also discussed. So, with this we are going to finish here.

Thank you very much.