Control and Tuning Methods in Switched Mode Power Converters
Prof. Santanu Kapat
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur

Module - 03
Fixed Frequency Control Methods
Lecture - 17
Combined Feedback and Feedforward Control

Welcome, this is lecture number 17. In this lecture, we are going to talk about Combined Feedback and Feedforward Control.

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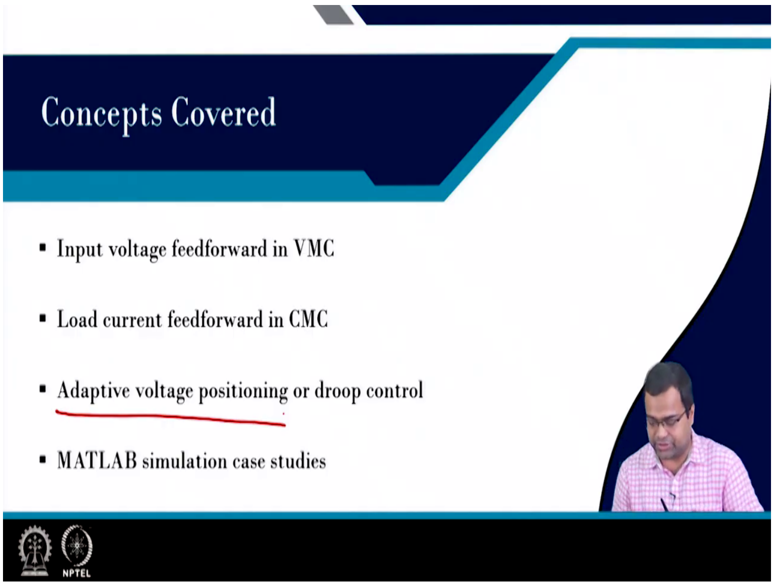

So, we have so far discussed a feedforward control without feedback first. I think it was in lecture number 14, then we have discussed in lecture number 15 with single loop and 2 loop control ok. So that means we are familiar with voltage mode control, which is a single loop control and we are also familiar with input voltage feedforward. So, this in this lecture we will consider combine load input voltage feedforward, in voltage mode control.

Here also the load current feedforward in current mode control ok. And, in subsequent lecture we will see, such combined feedforward control can actually significantly change the loop gain characteristics. Because we will see in voltage mode control in the future, we will see, the loop gain is dependent on input voltage, but by incorporating feedforward input voltage, we can make the loop gain more or less insensitive to input voltage. Similarly, in current mode control, we will see that is why voltage mode control suffers from poor line regulation. And, current mode control suffers from poor load regulation, but by means of load current feedforward, we can make this you know loop gain more or less insensitive to load current. And, we can achieve excellent transient performance as well as disturbance ejection.

Then, also we want to see adaptive voltage positioning or droop control, because this droop control is used in generally it is used very much in microgrid application, even in LED driving application. But it is also used in processor power supply, where the terminology is called adaptive voltage positioning ok.

Because this can use, this can be used to achieve nearly resistive output impedance. So that means it can respond to the transient almost immediately. And, we will see this in today's lecture using MATLAB simulation.

So, all this input voltage load current feedforward as well as adaptive voltage positioning or droop control, we also want to show MATLAB simulation case study demonstration.

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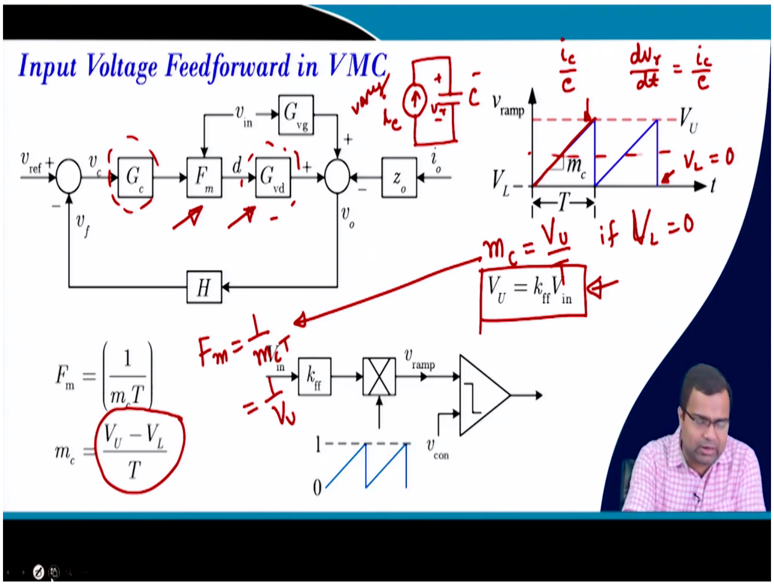

So, first input voltage feedforward. You know we know already about this loop gain though we are not familiar with this transfer function, because we have not I know covered yet the small-signal model. But, assume that because that will be discussed in the subsequent lecture, but assume that, you know this there is a transfer function which can be derived, which actually captures frequency response of the output voltage with change in duty ratio.

This is a modulator gain and that we have discussed, because that if we are using a sawtooth waveform and the sawtooth waveform the voltage magnitude the peak voltage, the modulator gain is one by that peak voltage. Then, the controller part although we have not discussed the design of controller, but here we are taking some controller. And I will show you that controller can be designed by if you provide some crossover frequency phase margin. But, the exact design process will be discussed in the subsequent lecture.

But, today we will take a compensator and we want to see the feedback closed loop control voltage mode control, and it is transient performance. Particularly the supply transient performance, there we want to see without feedforward and with feedforward what is happening.

Now, here the voltage mode control we consider a sawtooth waveform, where m c is the slope of this ramp. And, this slope of this ramp is nothing but what is the slope of this ramp? The slope of this ramp is nothing but the upper limit of voltage minus lower mean by T. So, here the lower limit we took V L is equal to 0, but sometime you can add some offset to keep it up or keep it down. Sometime this voltage can be symmetric with respect to 0 right not symmetric I will say, we can take this base value; that means, V u half of the V u will be negative half positive.

So, there are many possibilities, but in most of the commercial application we generally take 0 to some maximum value voltage. So, in that case, it is simply m c will be nothing but V upper by T, if V sorry if V lower equal to 0. And, what is modulator gain? The modulator gain here is the modulator gain is 1 by if this is the case it is 1 by m c T which is nothing but 1 by simply V u ok, there is a maximum voltage.

Now, we have discussed in lecture number 14 in the feedforward; we need to incorporate the upper voltage, which or basically the slope of this ramp is proportional to the input voltage. And, we also discuss in integrated circuit how can I do that, because generally these waveforms are generated by using a constant current charging a capacitor. So, the output of the capacitor will look like a sawtooth waveform.

Now, the slope of this sawtooth waveform decided by two factor; that means, if I charge a constant current, a constant current charging a capacitor ok. So, this magnitude of this constant current and the capacitor that means, what is the slope? The slope is nothing but the i c by c ok. This is our ramp voltage v r d v r d t, which is the slope.

Here, i c is the current source, and it is constant and capacitor c is constant. So, if the capacitor is constant, then the slope can be varied by varying the magnitude of the constant current; that means, we can vary this quantity, we can vary this quantity, we can vary it. And, if you vary in proportion to input voltage, then we can realize this actually this feedforwad action ok.

So, here it is in the simulink model I am showing, but in the actual circuit I told you that it can be implemented ok. So, by this in simulink we are going to implement this, but at circuit level we can implement by using this current source. In fact, we can do it in simulink also no problem, so ramp.

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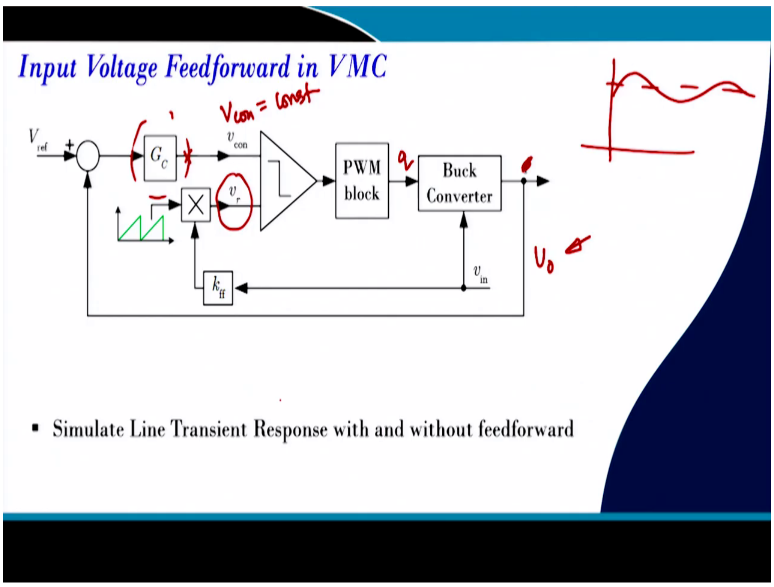

Now, next input voltage feedforward, in the previous lecture when we consider open loop we have disconnected this loop. We have taken a constant; you know this to be constant, something like a constant ok. So, we have disconnected this loop and then we applied a constant voltage and then we have considered the input voltage feedforward into this sawtooth waveform.

And, we saw there is a drastic disturbance rejection, even using open loop converter by means of input voltage feedforward, when the converter undergoes a step change in the supply voltage. This is also true if your supply has distortion; your supply has some distortion along with the fixed value.

And, in lecture number 13, we have discussed, if you consider an I practical voltage source and if the practical voltage source has some impedance or if you have if you connect poorly connect the wire cable of your power converter. If the supply is not very well regulated, then this output impedance of the supply, which may include the cable resistance, also can drastically change the behavior of the source voltage of across the buck converter when, it is driving a DC D C converter. Because your buck converter has a pulsating input current or discontinuous input current.

So, that will introduce an oscillatory behavior. In fact, the profile of switching will also appear there, and such behavior in the sub source can get reflected in the output. That means, it can be reflected in the output, which is here, this is output.

So, sorry this is not q; q is actually going to this PWM box, this is q the output voltage. This can substantially you know this an effect can and if can be reflected in the supply and output and that is not desirable. By means of heat power you can almost reject the disturbance that is first thing, ok.

That is one thing that we will discuss. In a closed loop, we are considering compensator and then adding this feedforward and we want to see what happens, ok.

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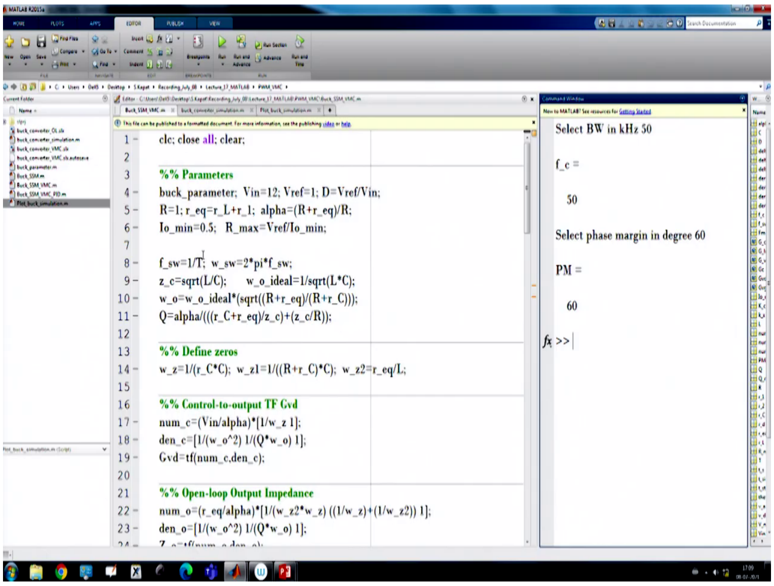

So, you want to simulate a case study with and without transient ok. Let us go back.

So, you do not need to know detail about this model, because we will discuss with all detail in the power point, when you come to the design stage. For the time being, we are assuming there is a compensator in the feedback loop and I am design, I have designed the compensator which will require the bandwidth or basically crossover frequency; I have set 50 Kilohertz, because 500 Kilohertz is my switching frequency.

And, I am keeping some 60 db phase margin. Now, the compensator is designed and this go to the buck converter directly.

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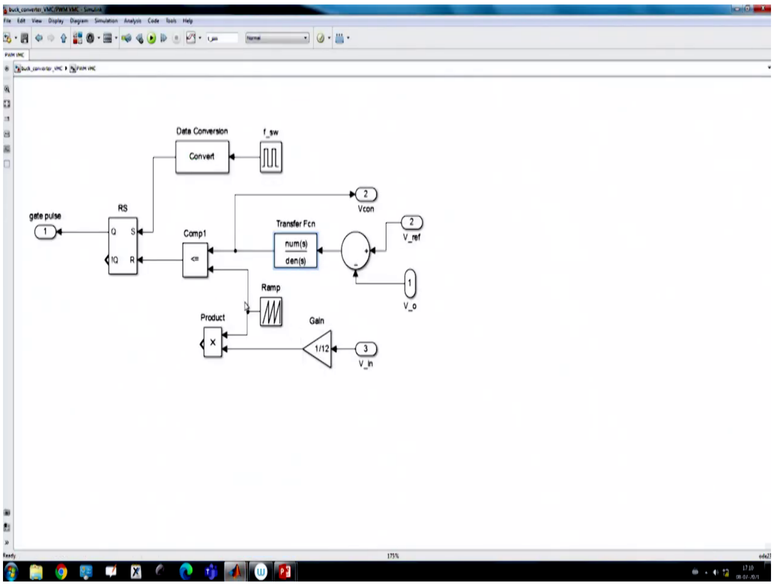

And, this takes the compensator directly from the MATLAB file. That means, you know if you remember that why we wanted to do the MATLAB based simulation interactive, because we can plug in everything from MATLAB and run the simulation from the MATLAB dot m file itself. We can make the design more interactive ok.

So, 60 and will come to this you know roughly in 34, 35, 36 lecture number. We will we will discuss in detail about this process of design as well as the MATLAB coding.

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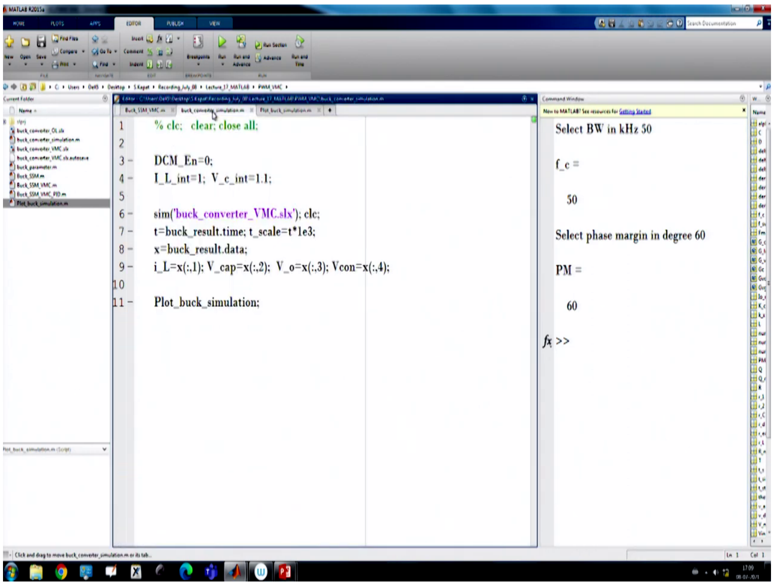

But, today I just want to discuss what will be that impact. So, we are making as transient, supply transient, ok.

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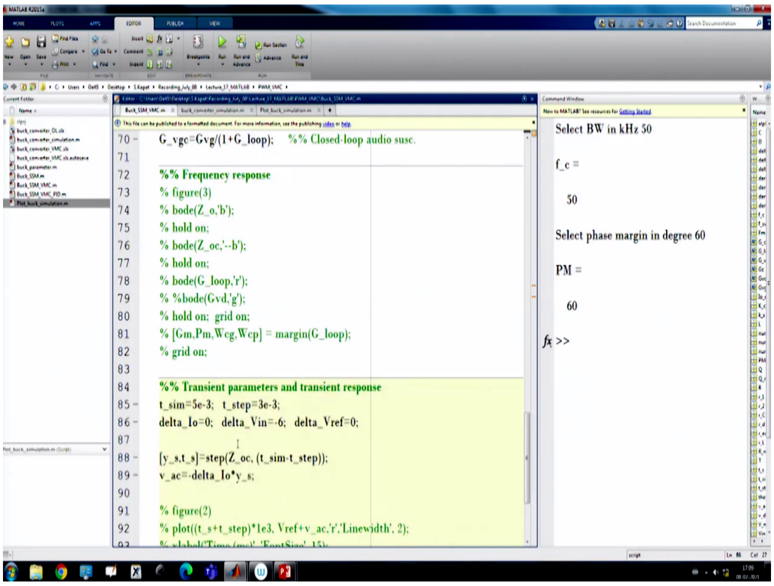

So, we are making a supply transient, where I have applied a supply of minus 6 volt; that means, the converter input voltage will change from 12 volt to 6 volt. So, minus 6 volt transient means initially 12 volt; that means, changes to 6 volt ok. Now, first thing I will see without feedforward, I want to run it ok.

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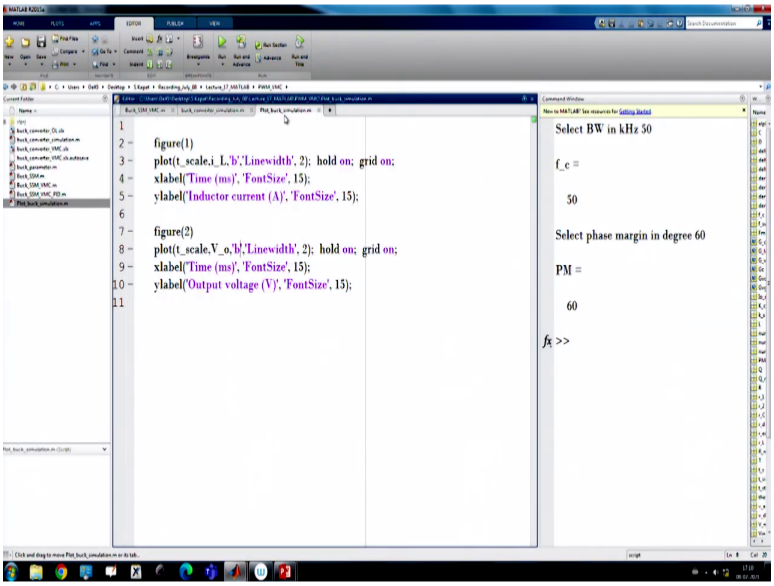

I will run it without feedforward.

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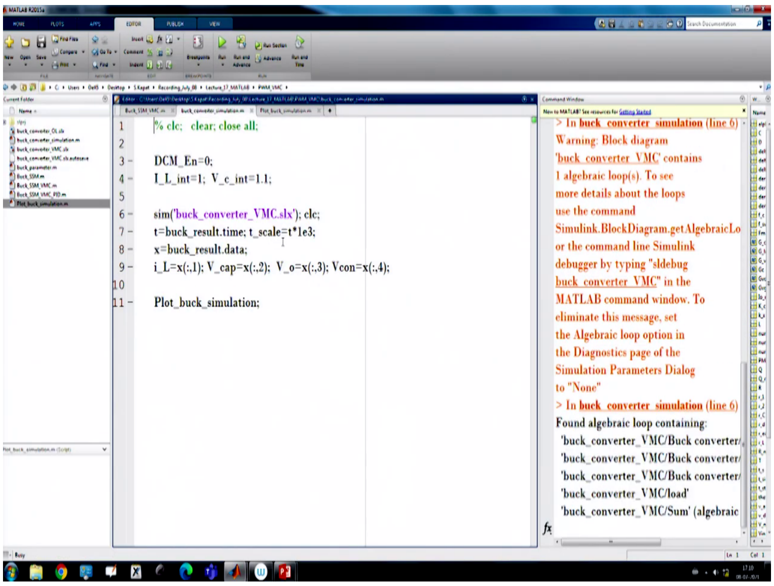

So, if I run the converter.

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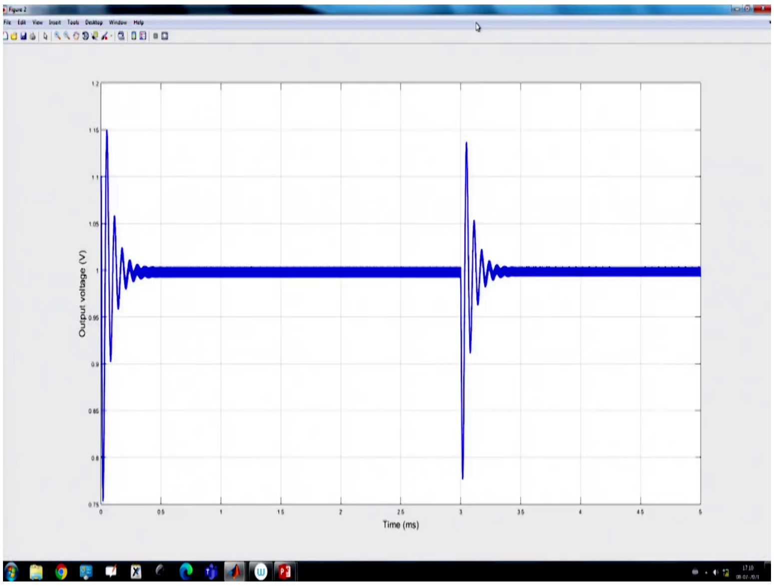

And I will show you the supply transient response using closed loop control, ok.

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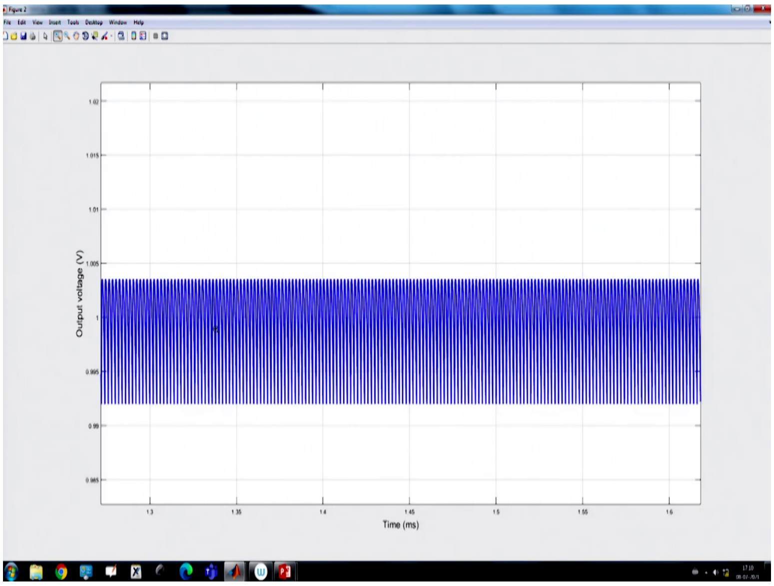

So, because of the closed loop you can see the output voltage is tightly regulated around 1 volt the average sense ok.

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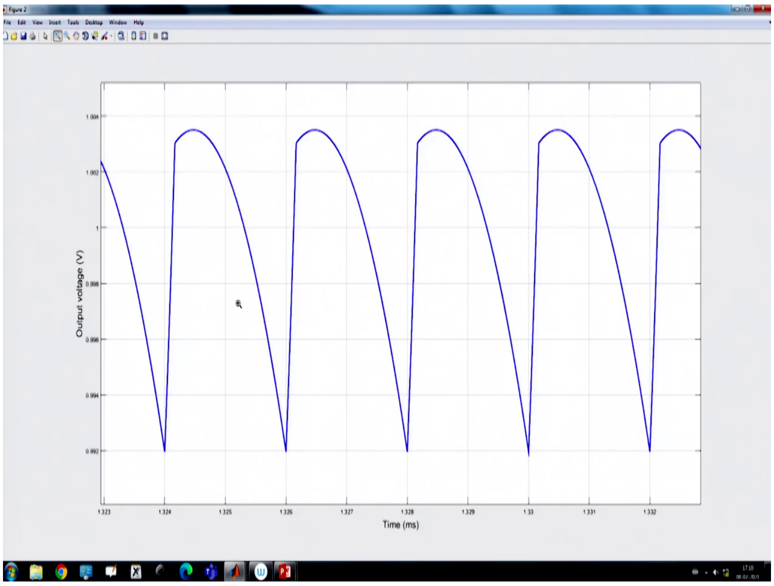

Which in open loop we saw, that if we apply a fixed duty ratio, it will never happen.

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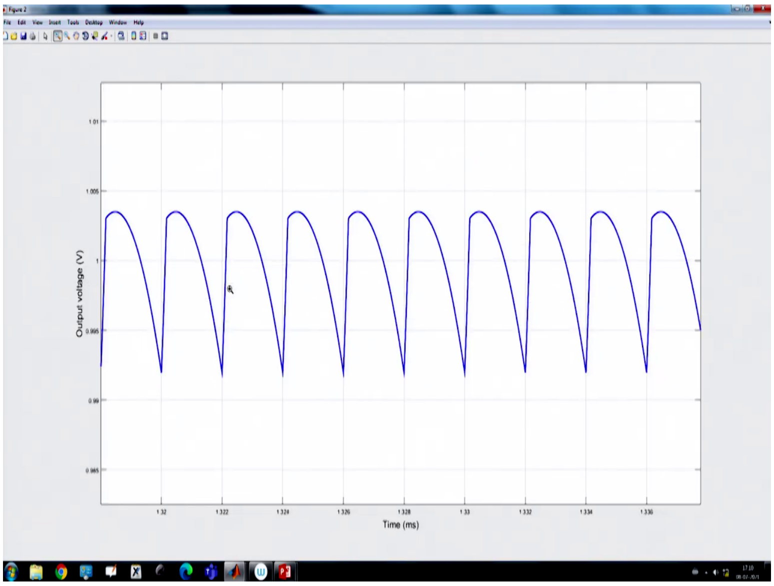

But in closed loop it is actually getting control.

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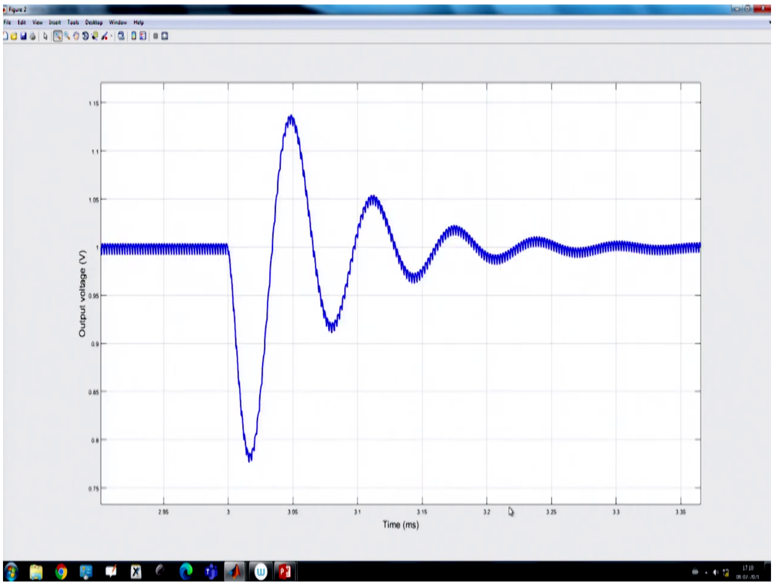

Also, now this transient behavior is under the closed loop control.

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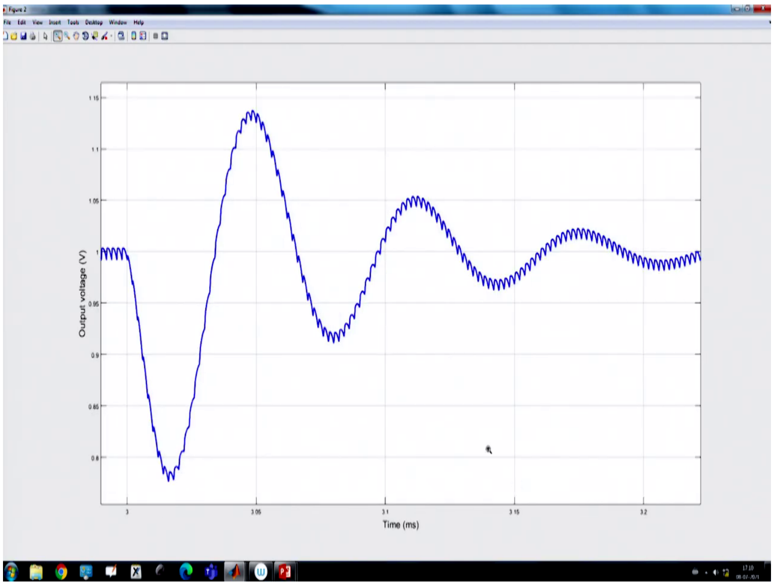

And you see, because of the supply step, there is a huge overshoot undershoot in this output voltage, and because you know even though we design the converter, but this effect is coming. So, we may have to you know design it. You know we have to try to reduce this effect by pushing the bandwidth higher.

So, one way to improve this, if we can increase the bandwidth, but that can; ok, let us do one thing.

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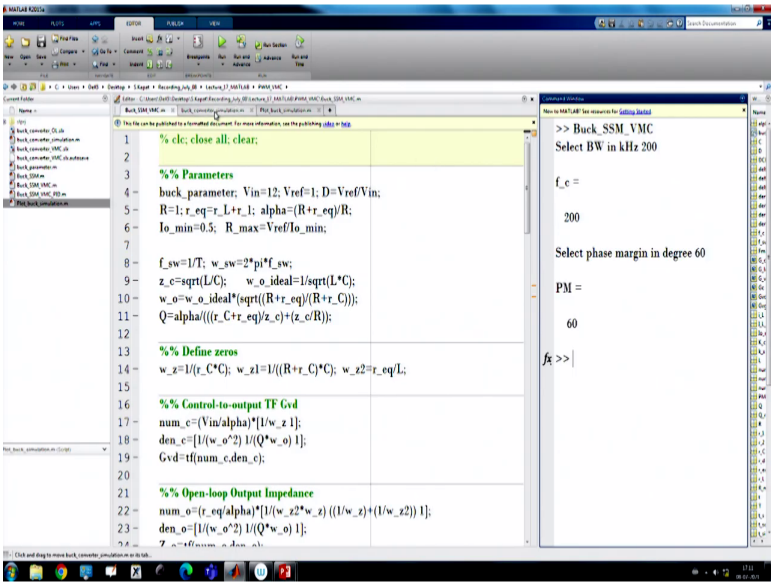

If, we try to push the bandwidth much higher; that means, if we run another case study with let us say we are going to 200 kilohertz, with 60 db. Although the model will not be valid that I will show you.

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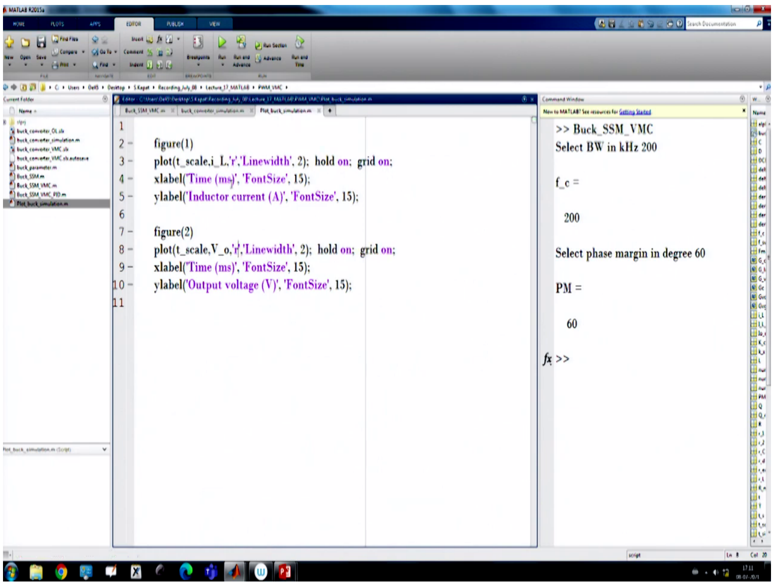

Next, I want to run the same thing using. So, I have increased the bandwidth of the closed loop converter.

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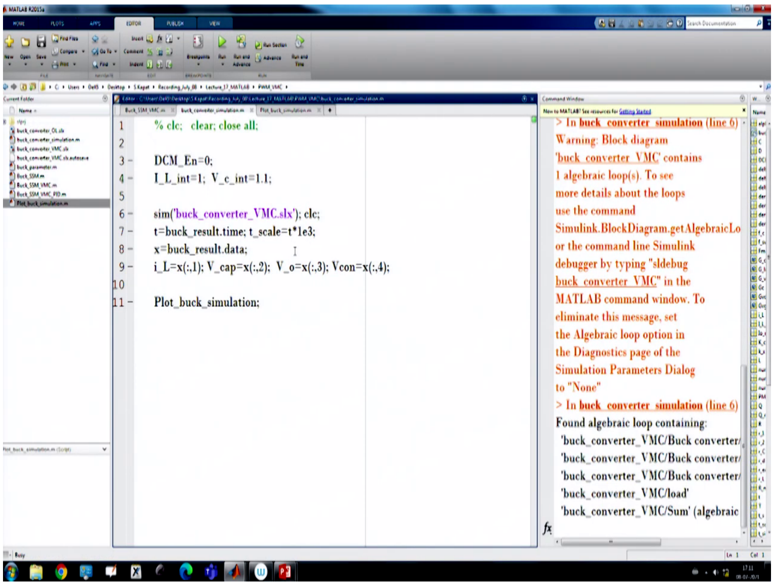

And, I want to see the response.

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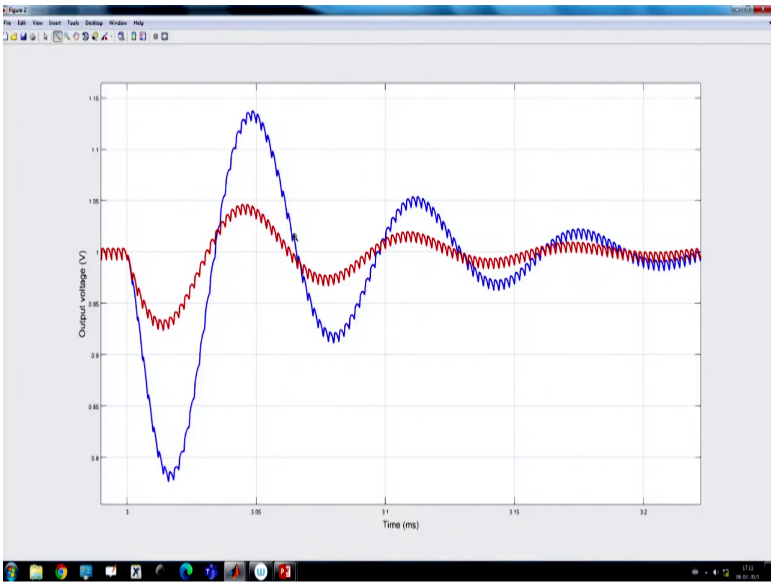

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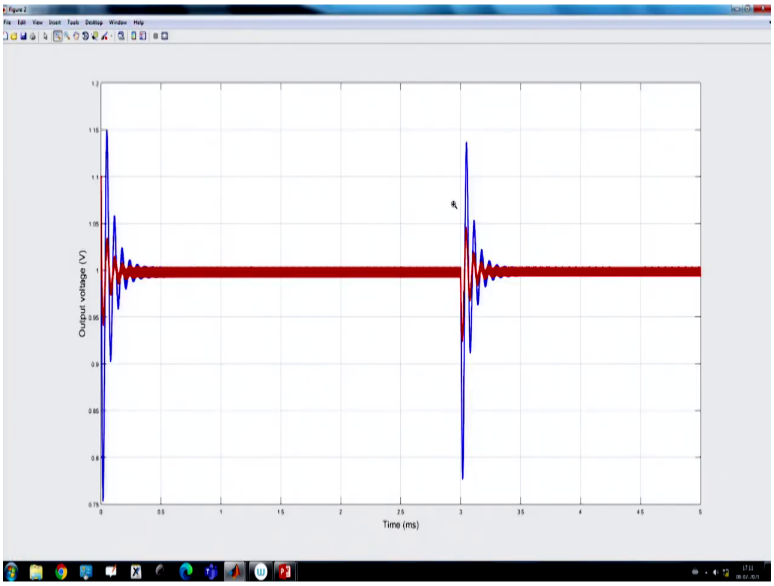

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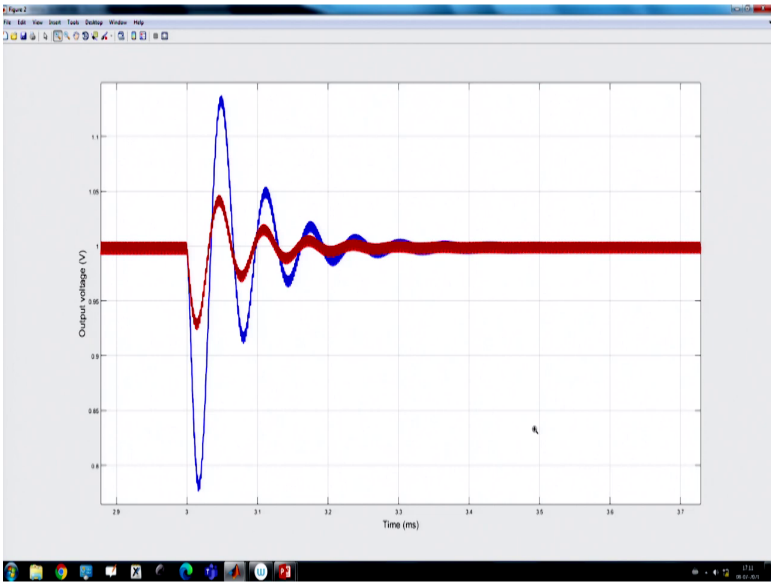

You know, the effect due to the supply is reduced by increasing bandwidth. And we will see this impact when you design closed loop control, because by increasing bandwidth you know loop gain crossover frequency.

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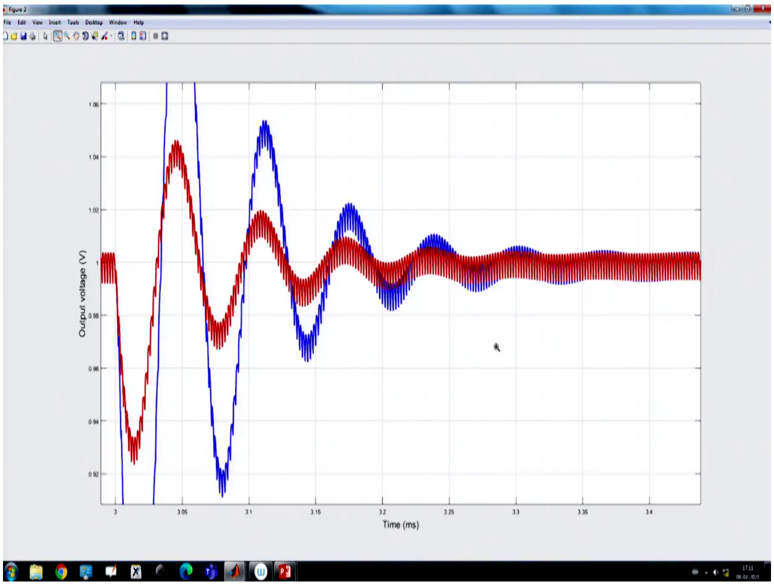

Or basically increasing by lifting up the loop gain, you can reduce the impact of the closed loop audio susceptibility. So, that part I am not discussing here. But, this is with much higher bandwidth ok.

Now, we want to move back to our earlier bandwidth, which is low bandwidth, now because this bandwidth model may not be valid, ok.

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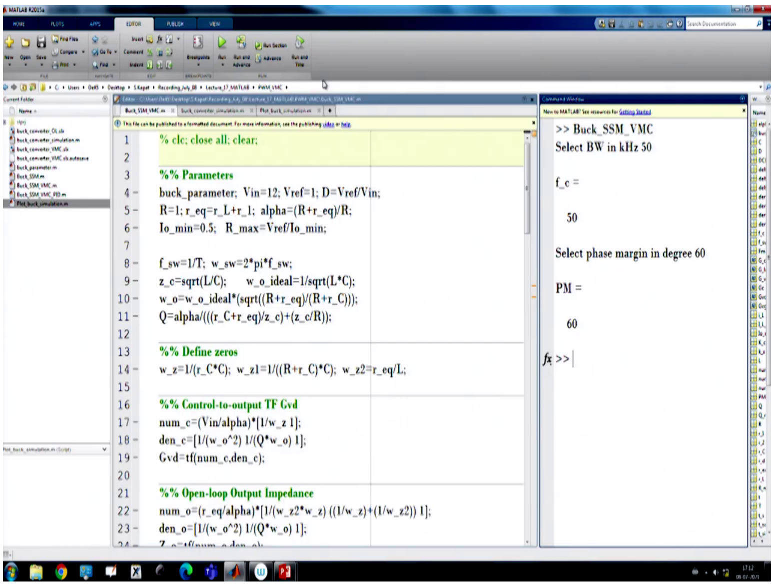

Here now, we want to run the earlier simulation with low bandwidth 60 db, which is the green one, but now with load current feedforward and we want to emulate this in the dotted line.

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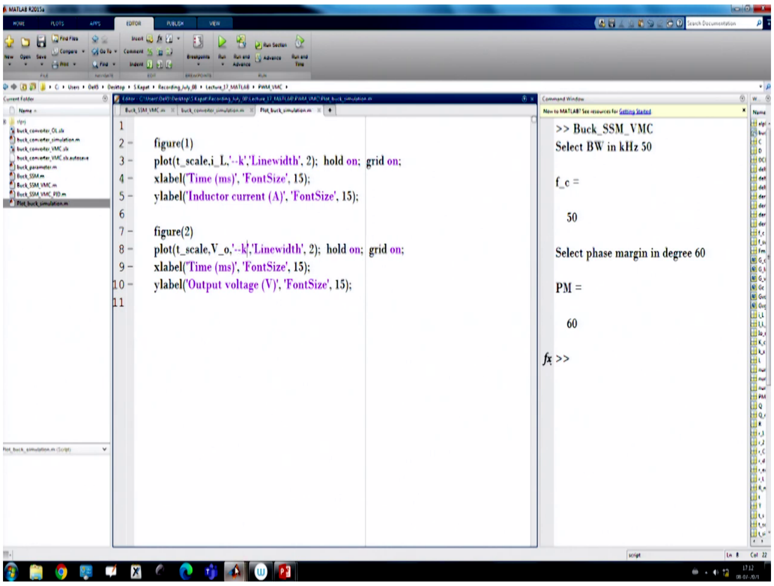

That means, let us say dotted black, black line. Now, we want to incorporate the feedforward action.

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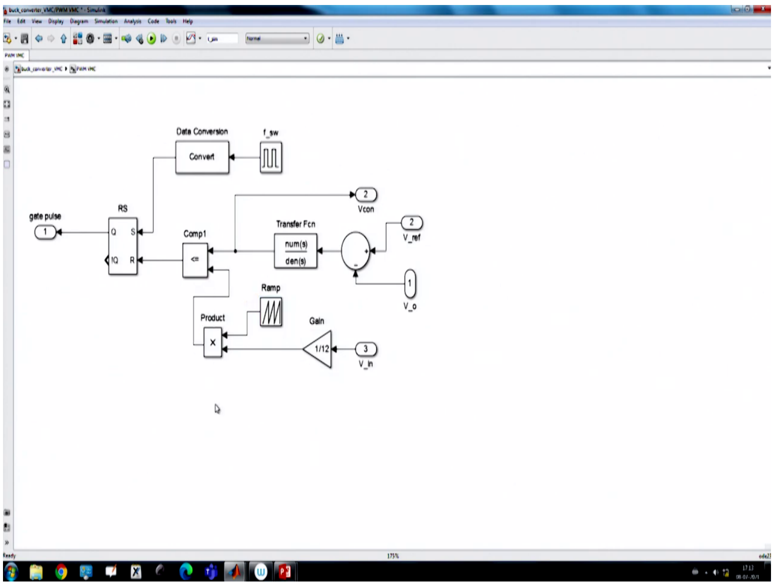

You know this is we are comparing with sawtooth. Now, if we use a product of this; that means, this is the product input voltage and I have taken the feedforward action 1 by 12; why, because at 12 volt input, this product into input voltage into gain will be 1. So that means, it will take the same sawtooth at 12 volt, but at 6 volt it will be half sawtooth ok.

But, we are adding a feedforward action and let us take it, let us take it ok, consider it. And, let us run the simulation.

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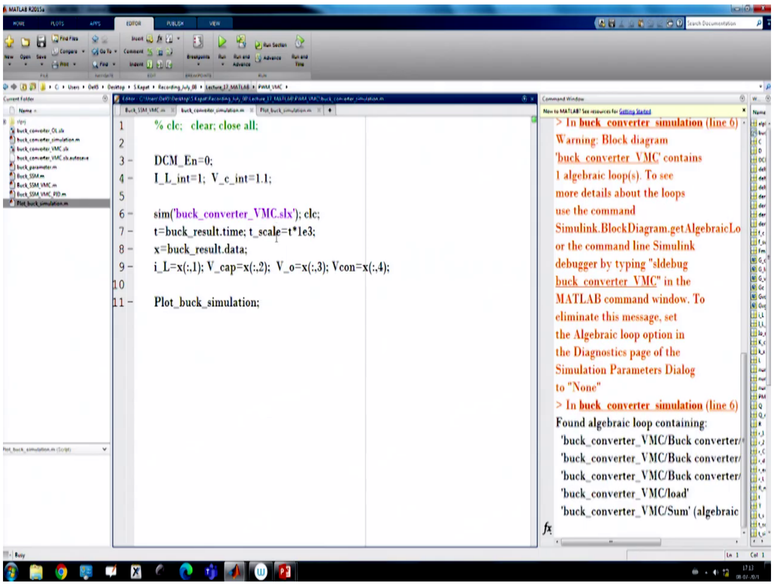

Now I am running this simulation ok.

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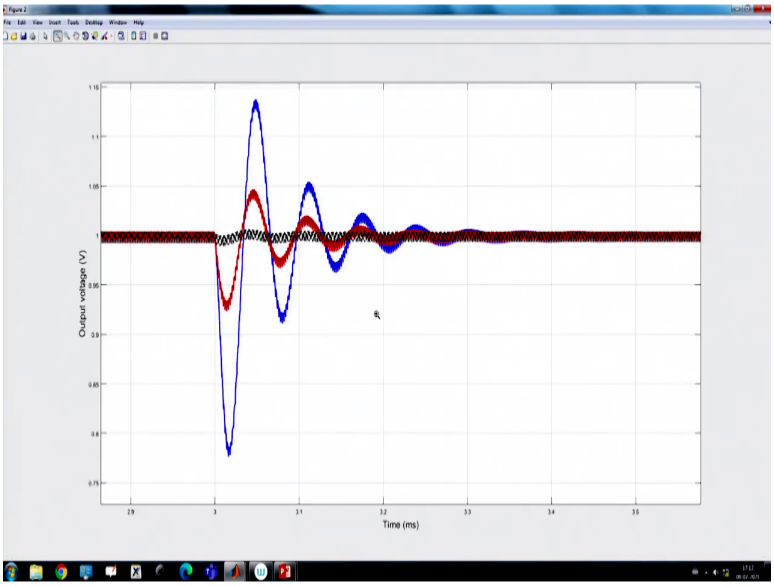

Now, the third one we are drawing.

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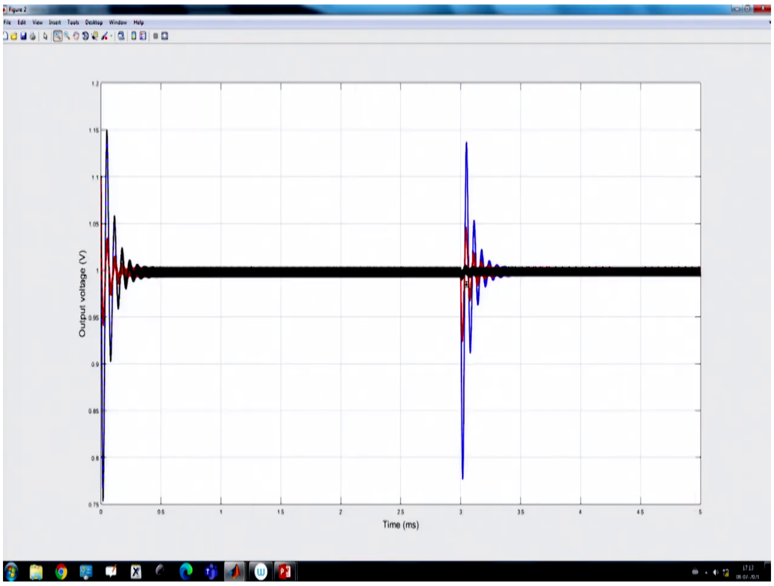

So now, this is the one the third one I am drawing.

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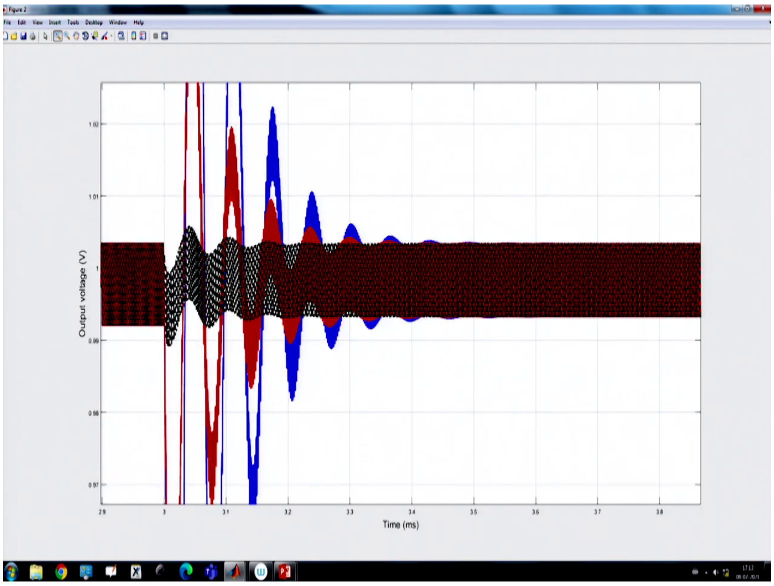

Which is the case.

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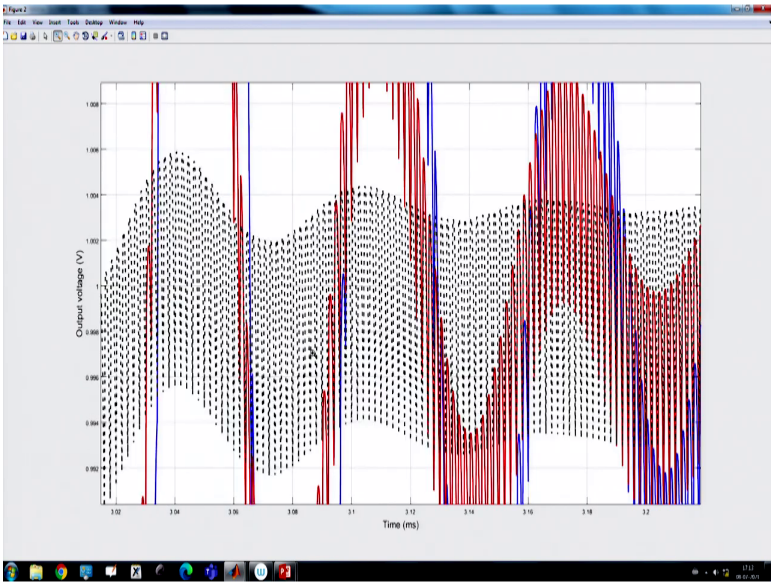

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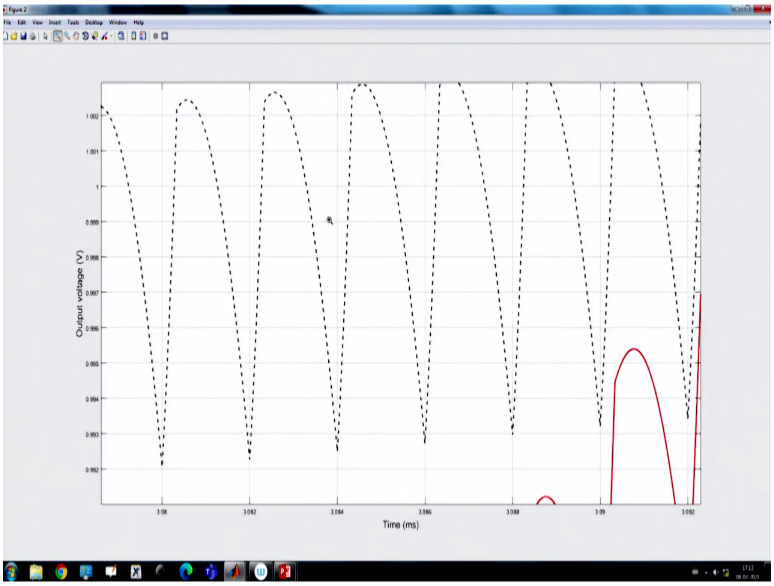

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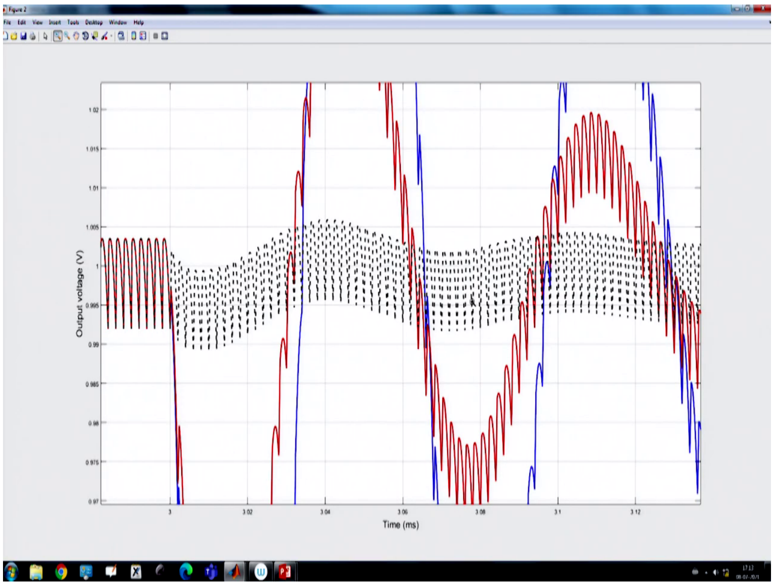

Just hold on, we will take the output waveform.

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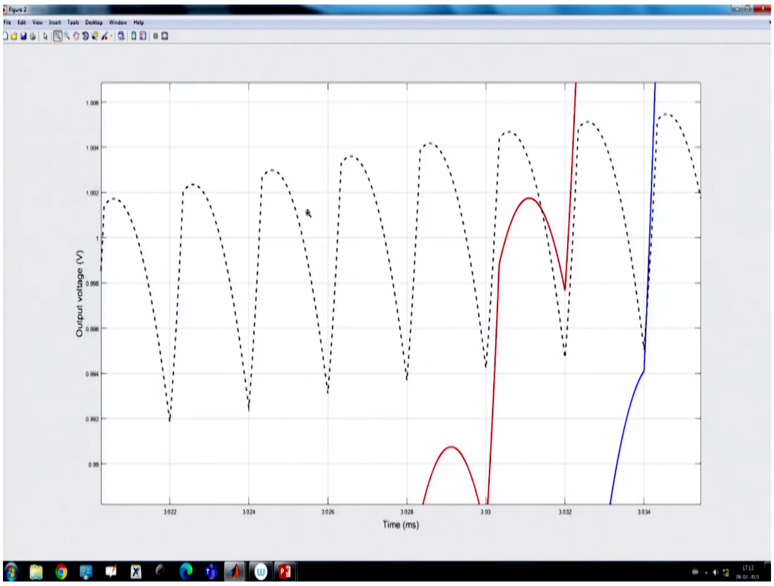

This is with feedforward action ok. So, we have added input voltage feedforward under closed loop.

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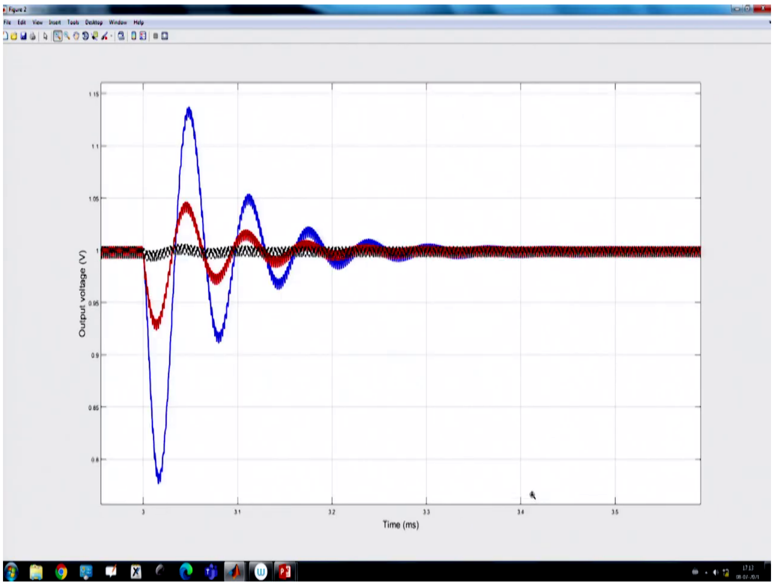

So, I am showing three different scenarios here. The blue one with 50 kilohertz bandwidth for a 500 kilohertz switching frequency; that means one tenth of the switching frequency. The red one both feedback no feedforward. Red one, we have increased the bandwidth to 200 kilohertz, for a 500 kilohertz switching frequency, although such bandwidth the model will not be valid. But, I am just you know for sake of because now we are not talking about model validity as if we increasing the gain. Just for sake of reducing the effect due to audio susceptibility.

So, that kind of bandwidth generally is not acceptable, because this is a very high bandwidth and it requires a very high loop gain, it may tend to saturate the error amplifier as well. But, in the third case, we have used the low bandwidth the same as the blue one.

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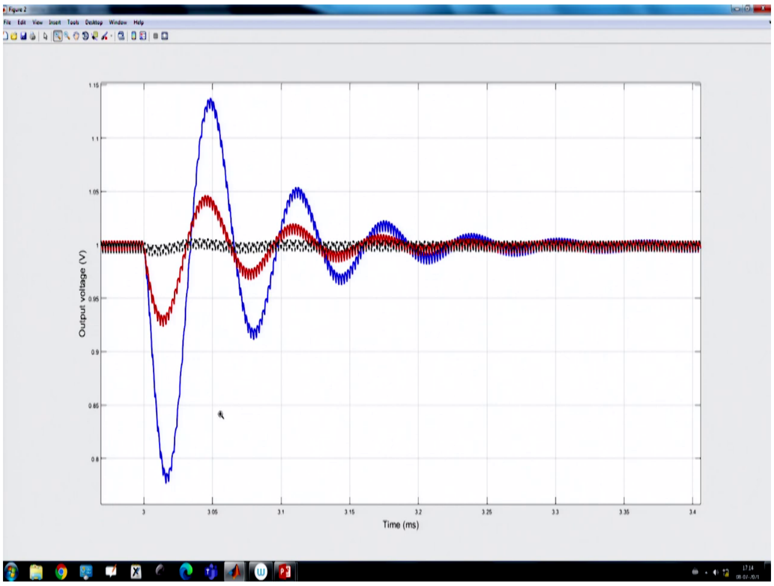

But same as the blue one same bandwidth, but with load feedforward.

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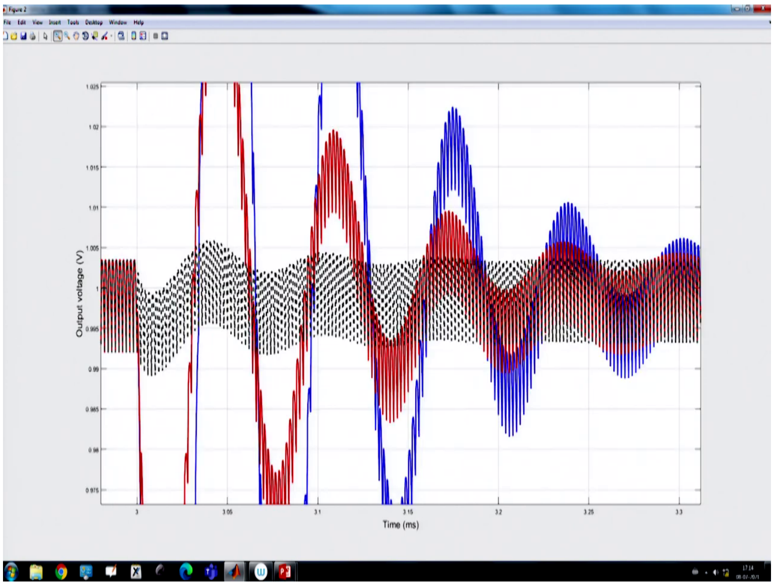

And, you see, the effect is almost insignificant, there is almost no effect on the supply behavior. So that means, this supply transient, if feedforward can drastically change the behavior. Another scenario I want to show you ok.

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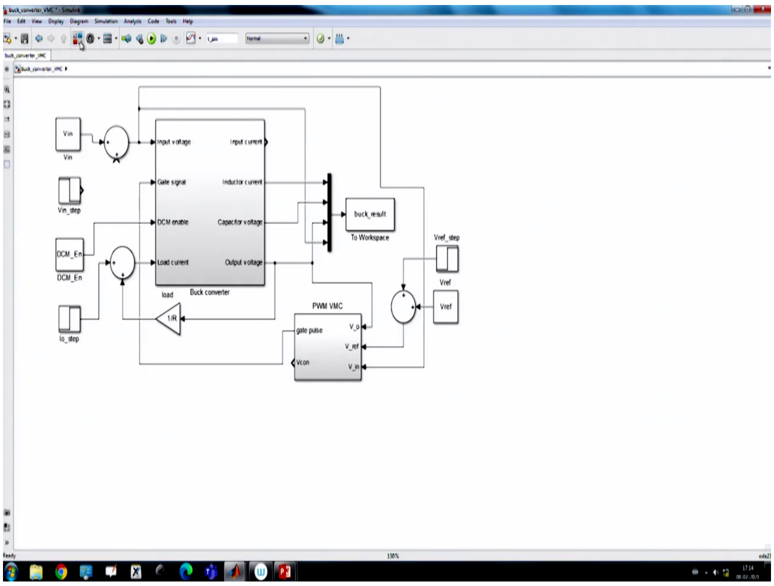

So, this is the one scenario I want to show you.

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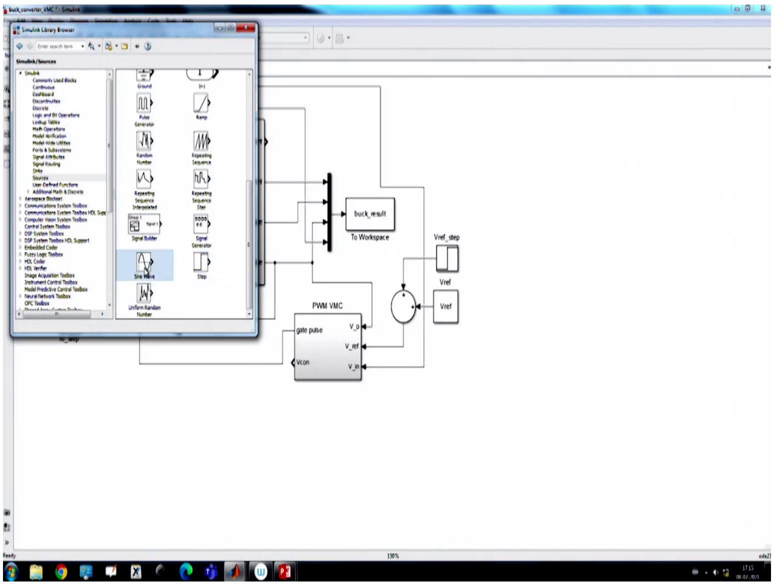

Suppose instead of a step, if I apply a let us say just hold on a sinusoidal input.

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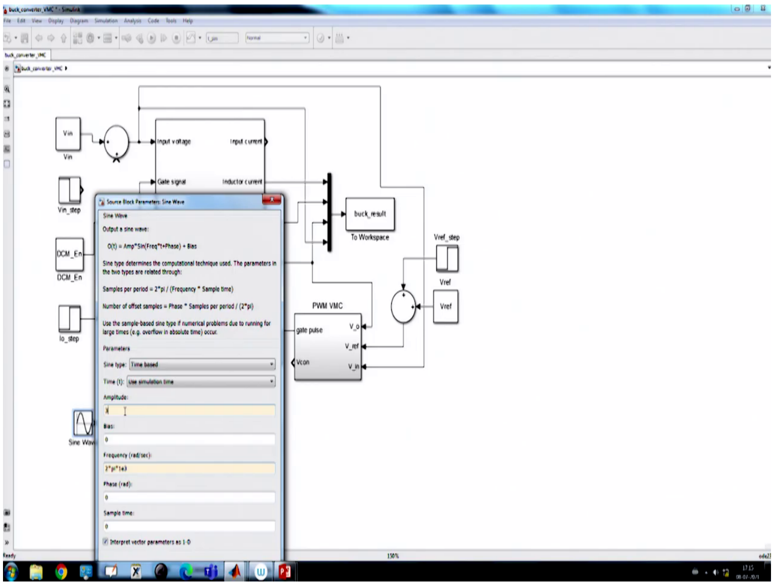

That means the sine wave with a frequency of let us say 2 pi we can add 1 kilohertz, 1 kilohertz, 1 e 3 ok, with the amplitude of let us say 2 or 3, ok.

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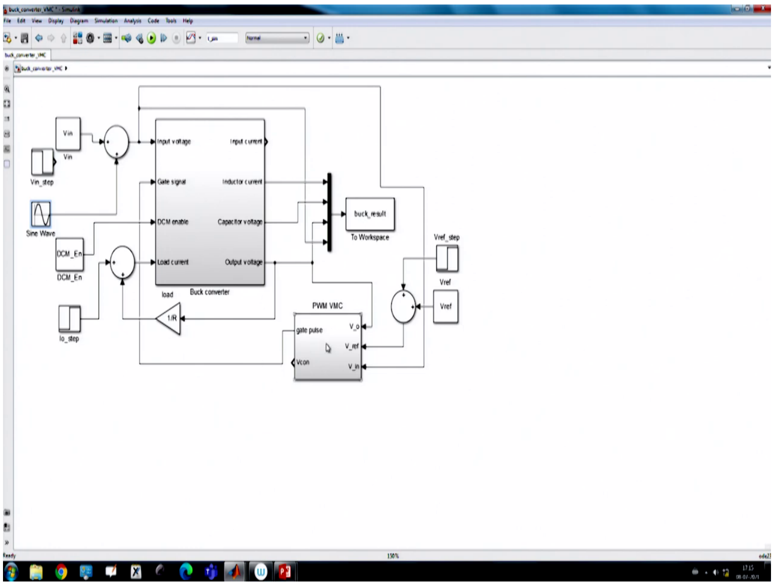

So, I am adding this ok. So, I am just for the time being I am now creating a simulation case study, ok.

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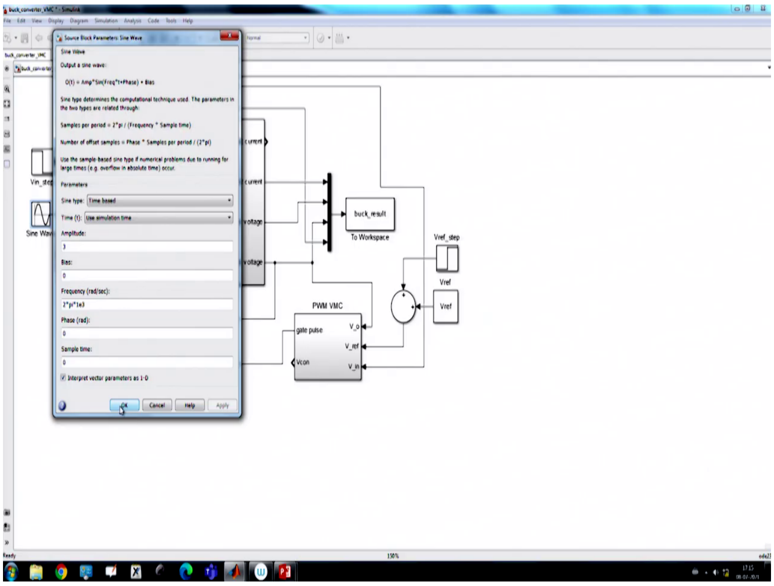

Now, here what I am doing, I am closing the whole thing and running the simulation.

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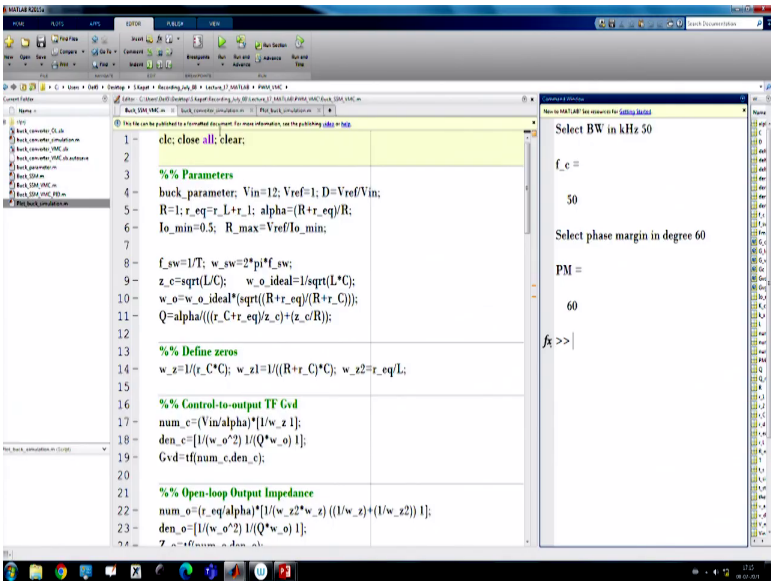

So, I am running with 50 kilohertz bandwidth 60 db phase margin.

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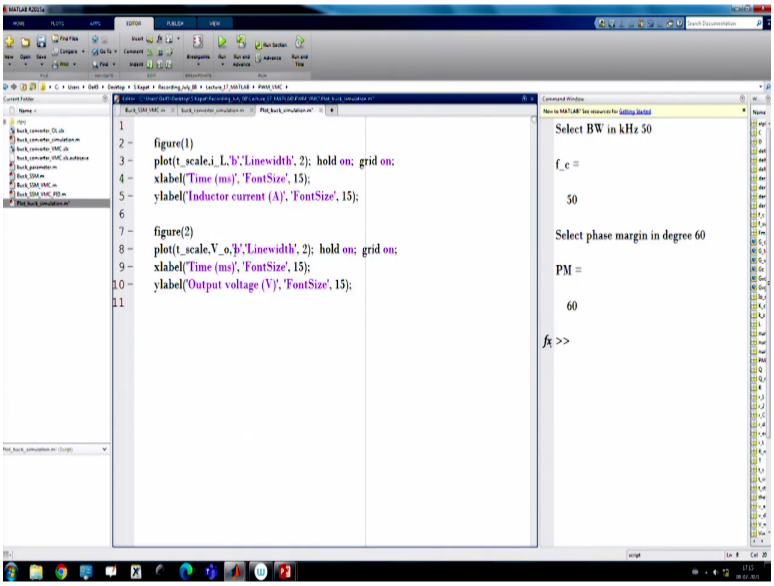
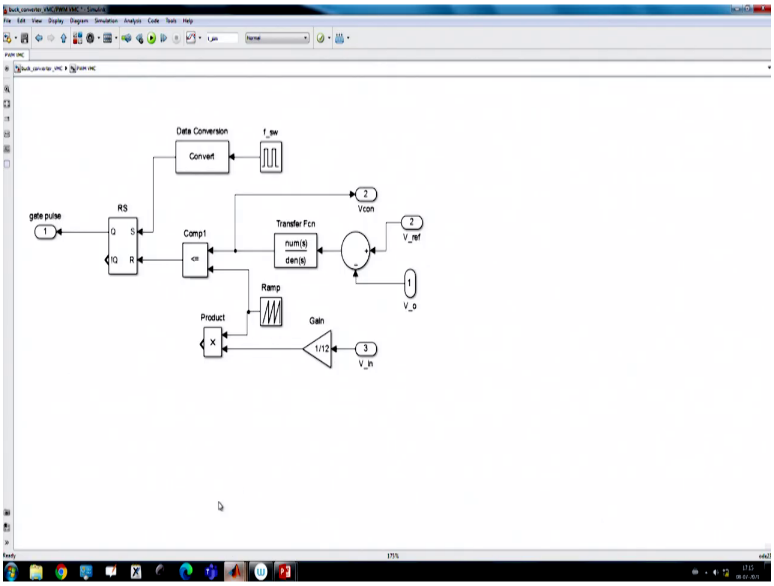


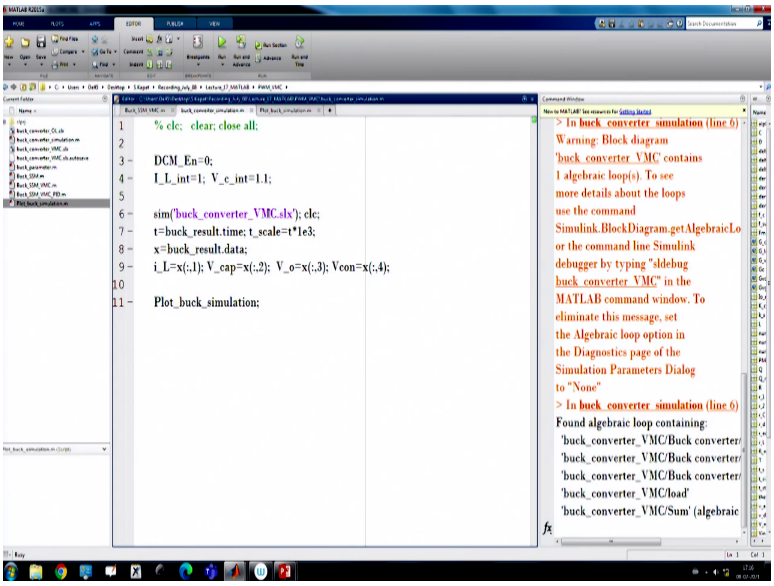
And, I am using a ray of blue trace, blue trace. So, initially I will not use any feedforward action.

(Refer Slide Time: 16:56)



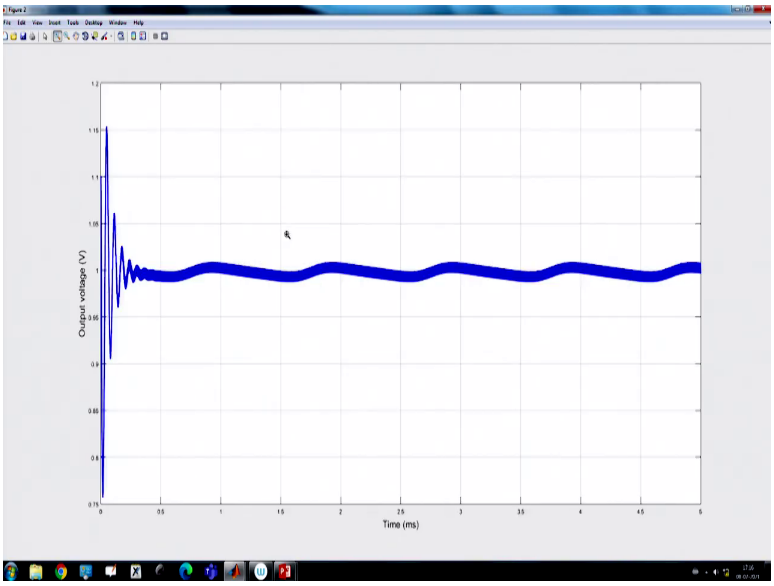
That means, if I go back initially, I will not take any feedforward action, ok.

(Refer Slide Time: 17:04)



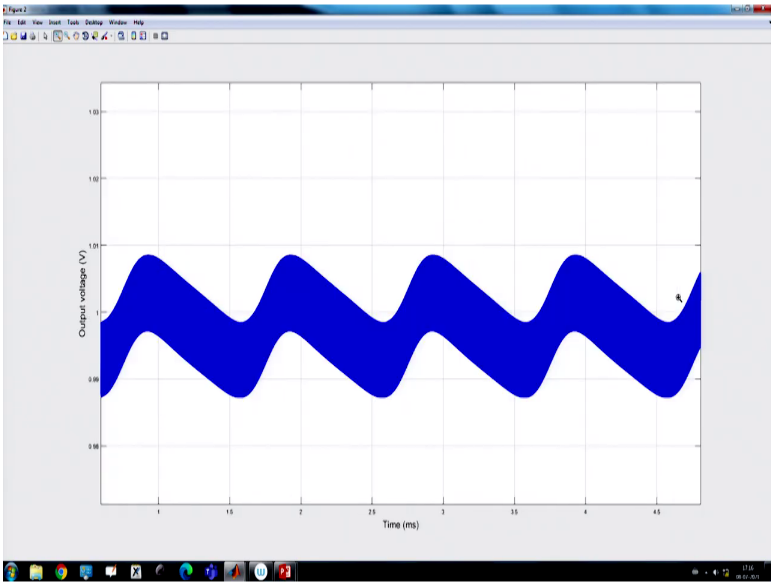
And, if I run it I want to show you, there is no ok.

(Refer Slide Time: 17:07)



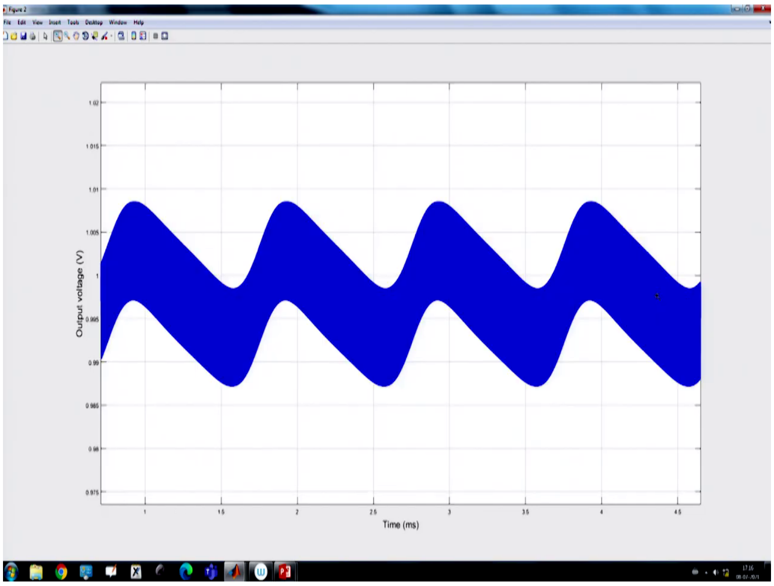
So, I need to stop the transient also ok, there is no transient.

(Refer Slide Time: 17:15)



So, you see the output voltage even it closed loop has a slow scale oscillation. And, if you see the frequency of oscillation, it is from 1 millisecond to 2 millisecond peak to peak. That means, the clearly that output frequency; that means the injected frequency component is reflected in the output.

(Refer Slide Time: 17:35)



And, which that means, if you recall, that we talked about source oscillation. So, even in voltage mode control, we can reduce the impact, but still some part is still there under voltage mode control, ok.

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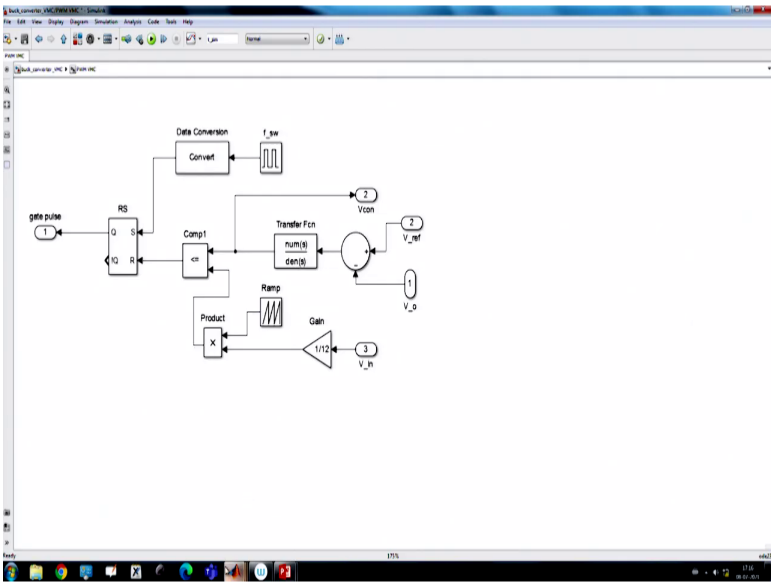
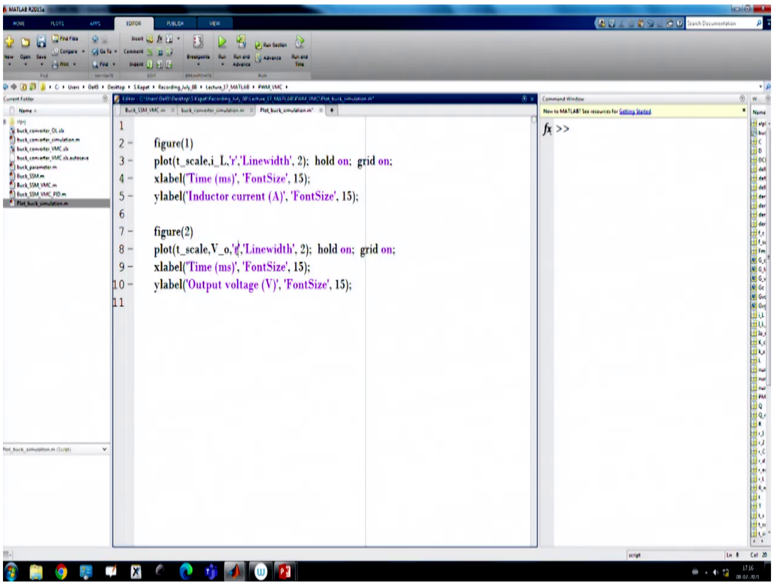


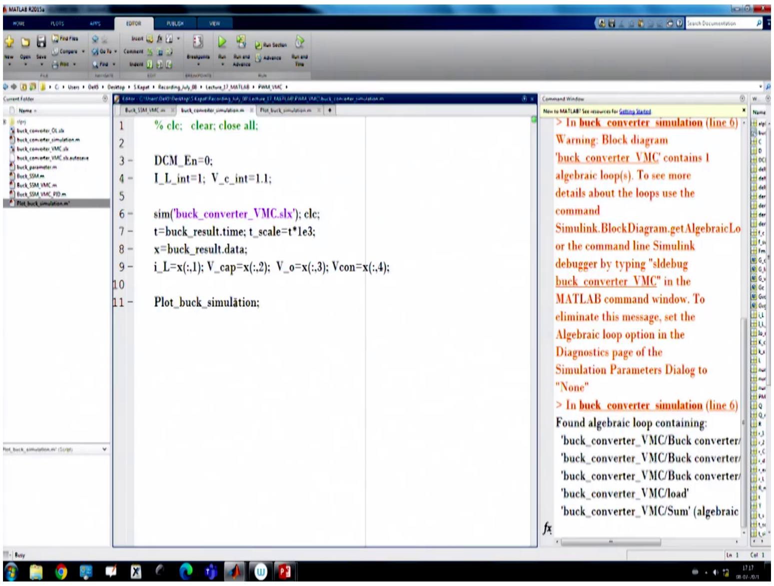
Now, how can we reduce this effect, can we reduce this effect, by means of feedforward action. So, that we want to see.

(Refer Slide Time: 17:59)



Now, we are doing feedforward action and we want to plot it, using a different color ok. So, let us use red color ok.

(Refer Slide Time: 18:04)



And, run the simulation again on top of this.

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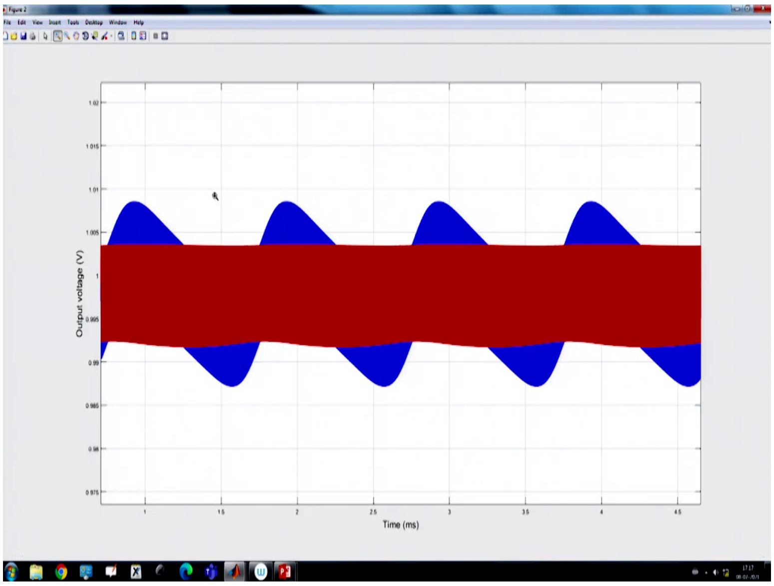
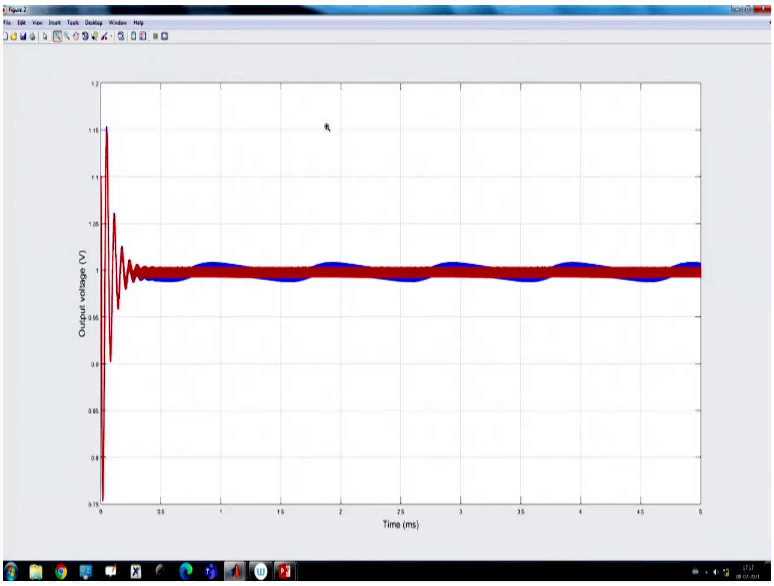
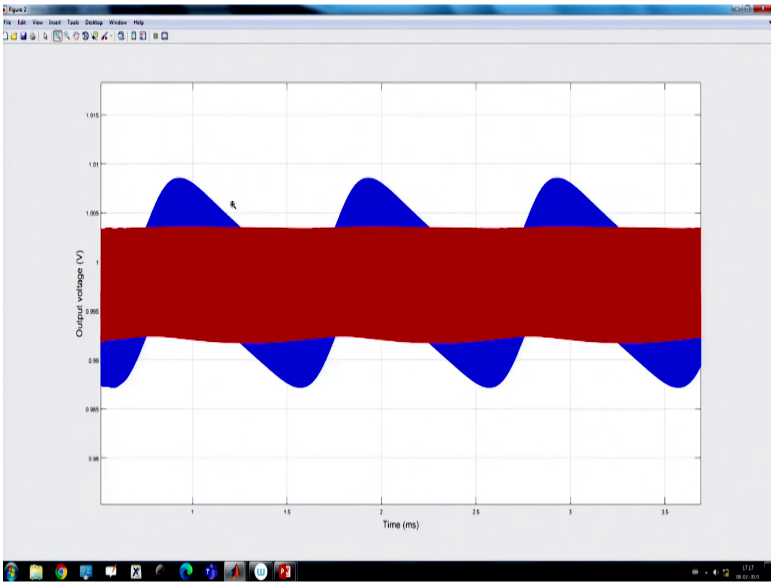


So, here.

(Refer Slide Time: 18:10)

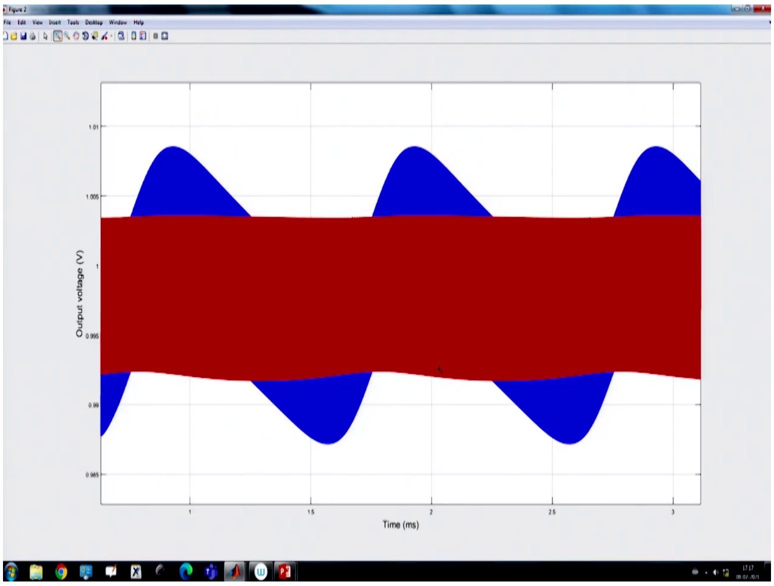


(Refer Slide Time: 18:12)



With feedforward action, you will see the effect is rejected.

(Refer Slide Time: 18:15)



That means your supply effect is almost nullified.

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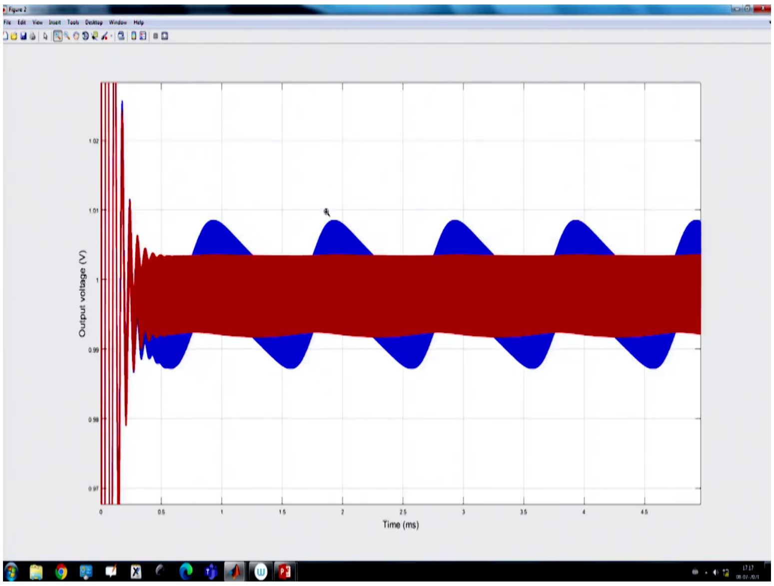
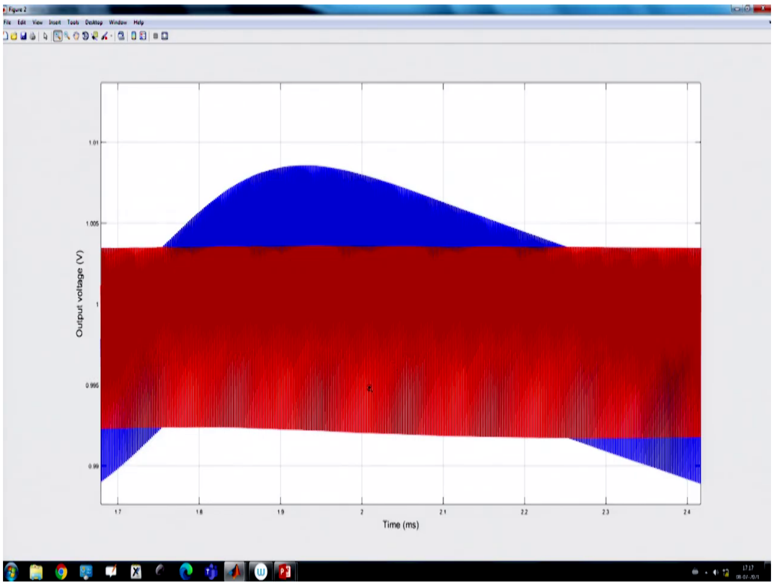


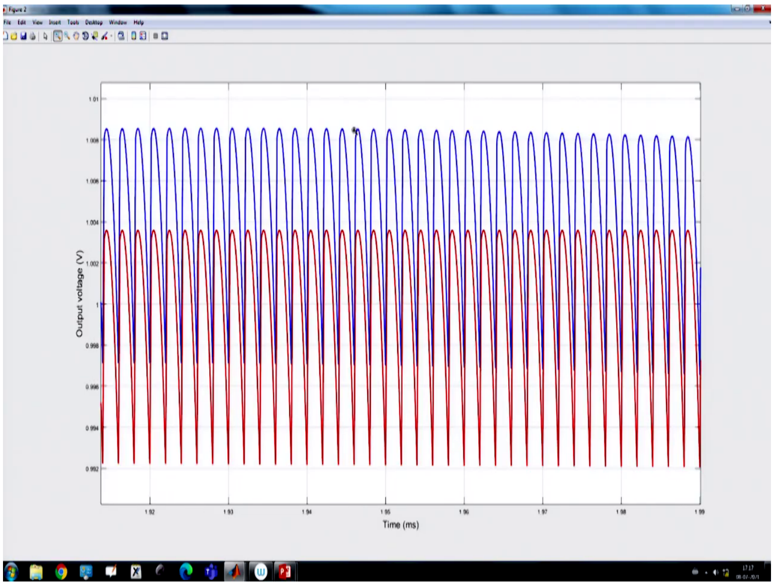
There is no disturbance in the supply even with you know input voltage fluctuation.

(Refer Slide Time: 18:20)



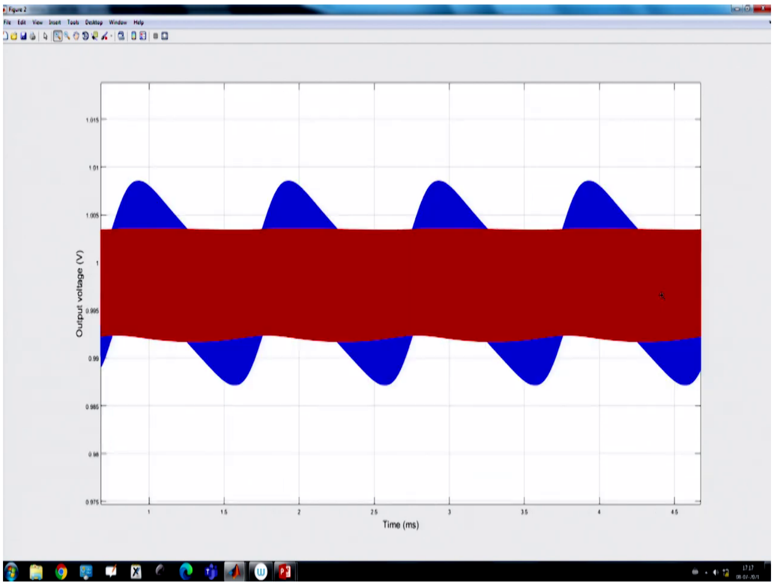
So, it is almost rejected.

(Refer Slide Time: 18:22)



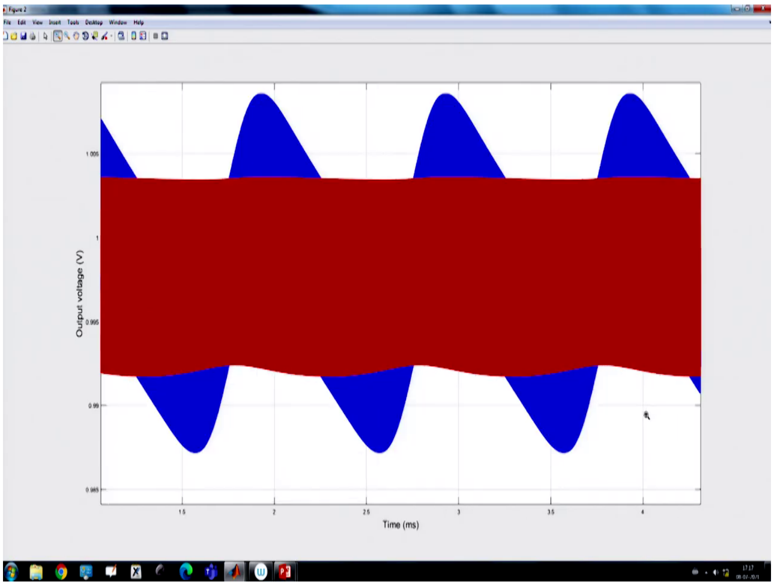
Because the feedforward.

(Refer Slide Time: 18:27)



So that means, even if you increase the frequency of oscillation or amplitude of oscillation, this feedforward action can this reject the supply variation.

(Refer Slide Time: 18:33)



So, we have checked that.

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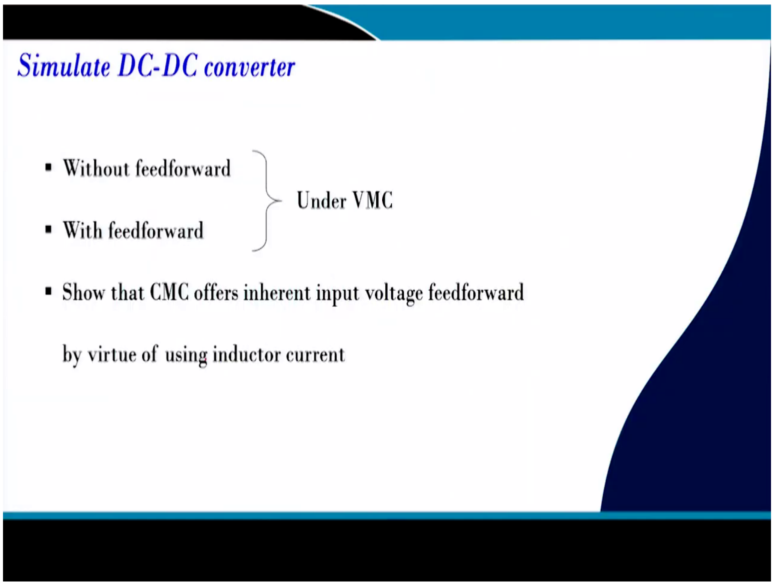

DC-DC converter with without feedforward, with feedforward under voltage mode control. Now, I want to show another effect, which is the same you know I want to create in current mode control ok.

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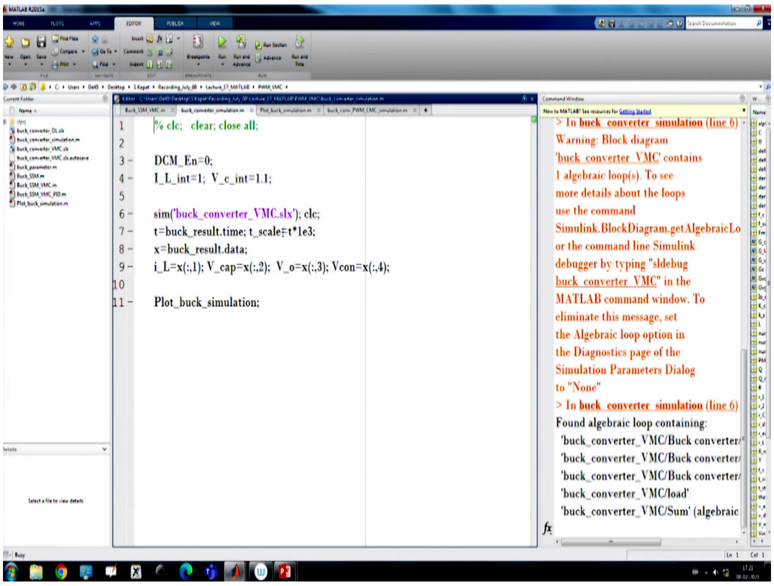

So, you want to run this first with the voltage mode control.

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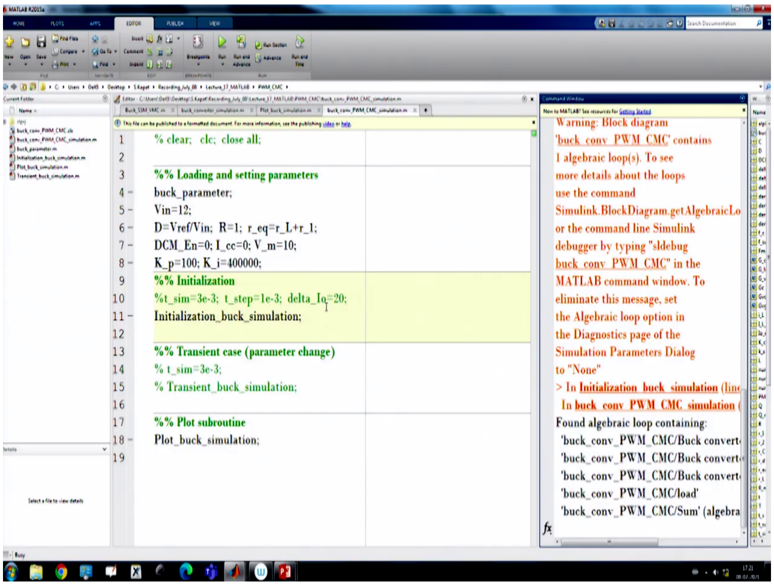
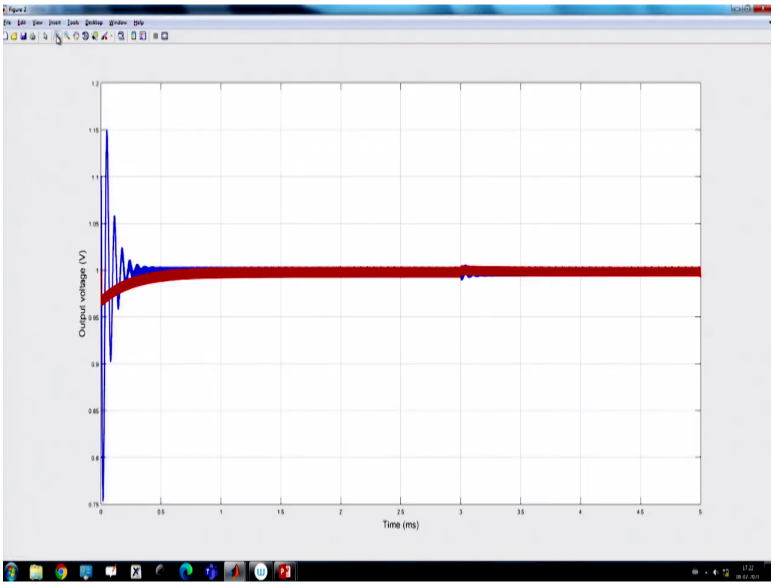


And let us run this simulation. Now, we want to repeat in current mode control go to current mode control and we want to run this condition, ok.

(Refer Slide Time: 19:12)



.

So, if you go here the same transient is happening.

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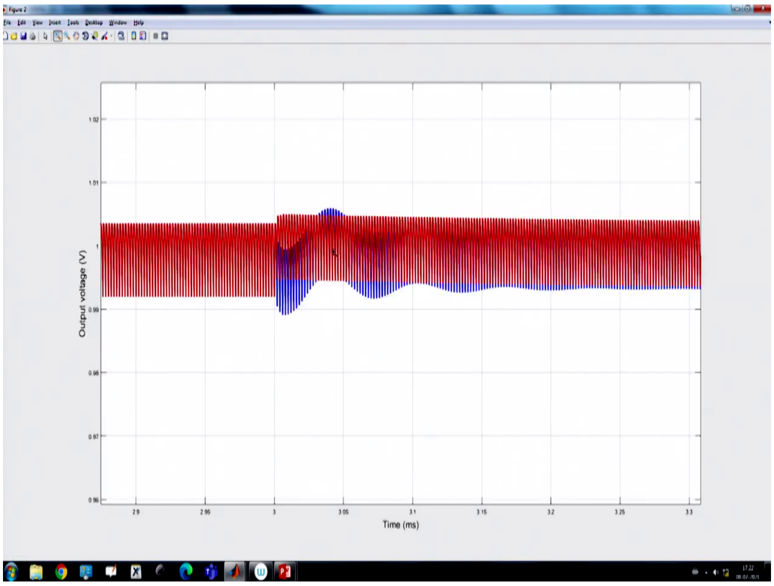
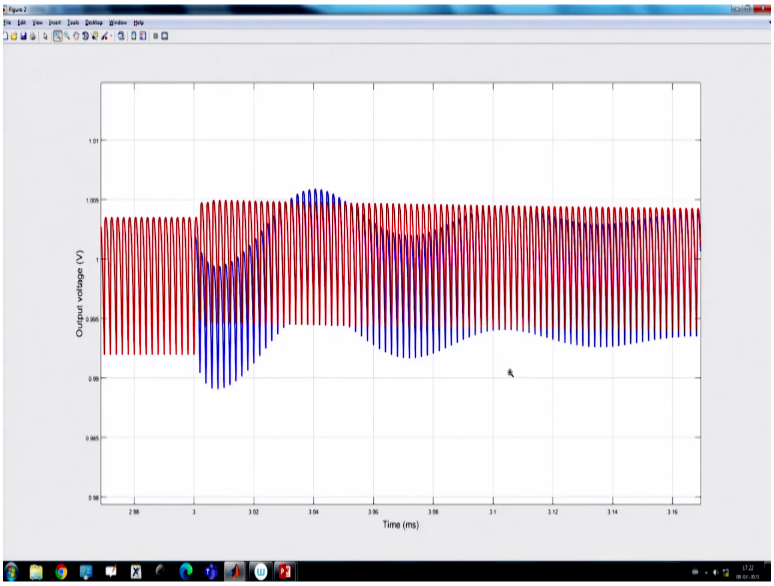


(Refer Slide Time: 19:17)



But, in current mode control, it has an inherent feedforward action. That means, it does not require any separate input voltage feedforward here ok; that is the beauty in the current mode control. That means, the current mode control offer inherent you know feedforward action that we can see here.

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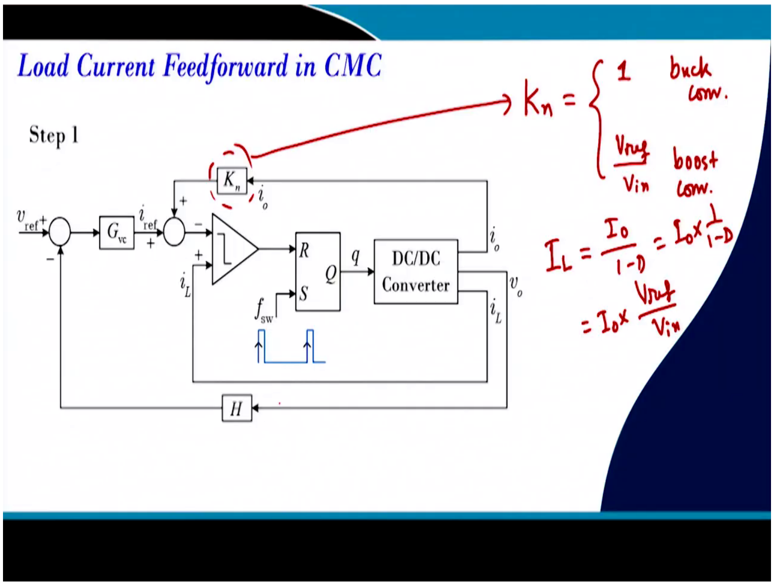
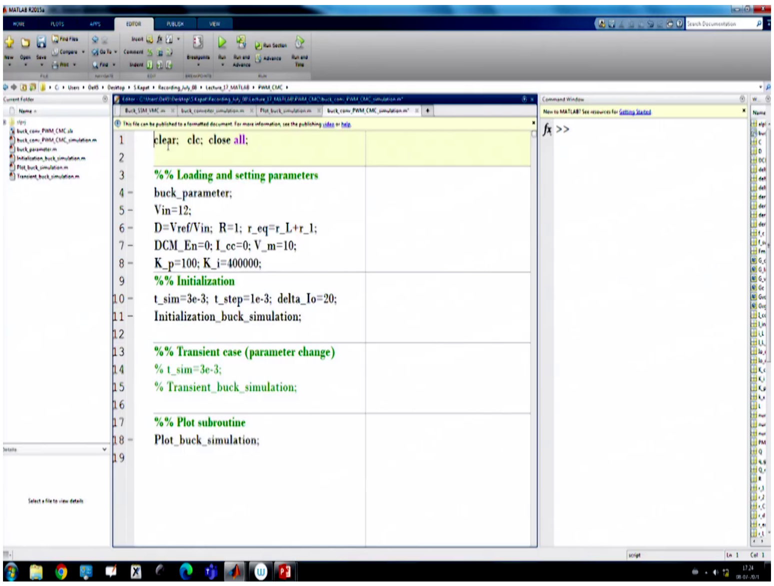


The step one we want to show with feedforward and without feedforward. That means, this is a normalized gain the load current feedforward, which can be added with the reference current or it can be subtracted from the inductor current. And, this normalized gain I am talking about this gain, this gain is equal to 1 for a buck converter. And, this is equal to v ref by v in for a boost converter. This gain is used to scale, the average inductor current; sorry load current to the same normalized ratio of the average inductor current.

That means for a boost converter, we know that average inductor current is equal to average load current divided by 1 minus D and 1 minus 1 by 1 energy is v ref by v in. That means, we know that average inductor current for a boost converter is equal to load current by 1 minus D. That means, it is nothing but I 0 into 1 by 1 minus D, and 1 by 1 minus D in a boost converter is nothing but output by input so, v ref by v in, ok. So, this normalization factor we have to do for a boost converter.

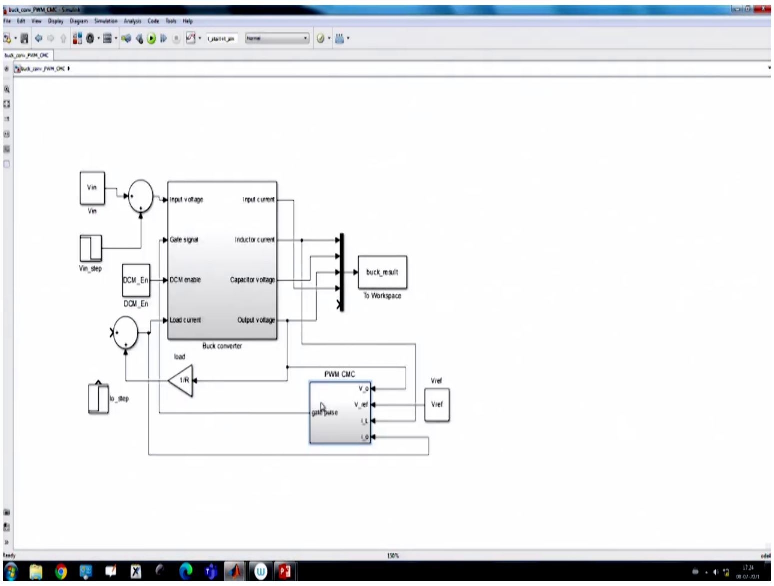
Now, I want to show three cases here. In the first case, let us go back to the current mode control simulation. Now, we are not talking about voltage mode anymore.

(Refer Slide Time: 21:08)

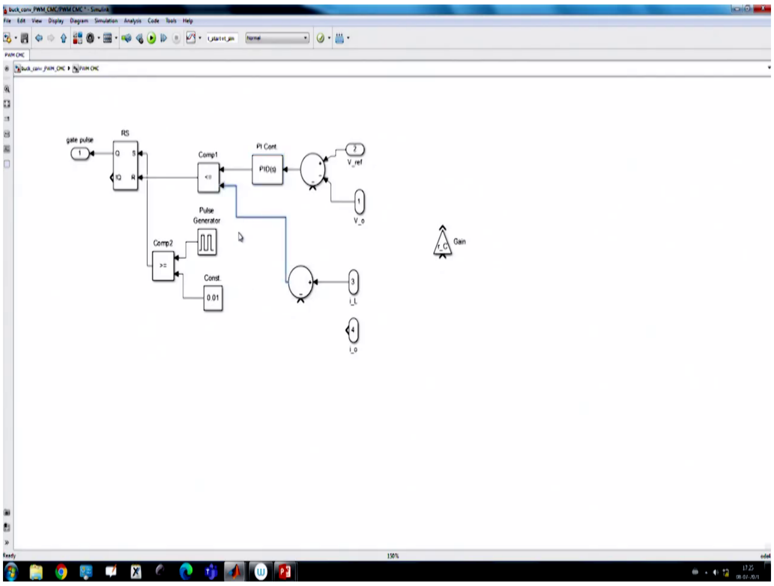


In current mode, we first want to consider ok, just 1 minute ok.

(Refer Slide Time: 21:22)

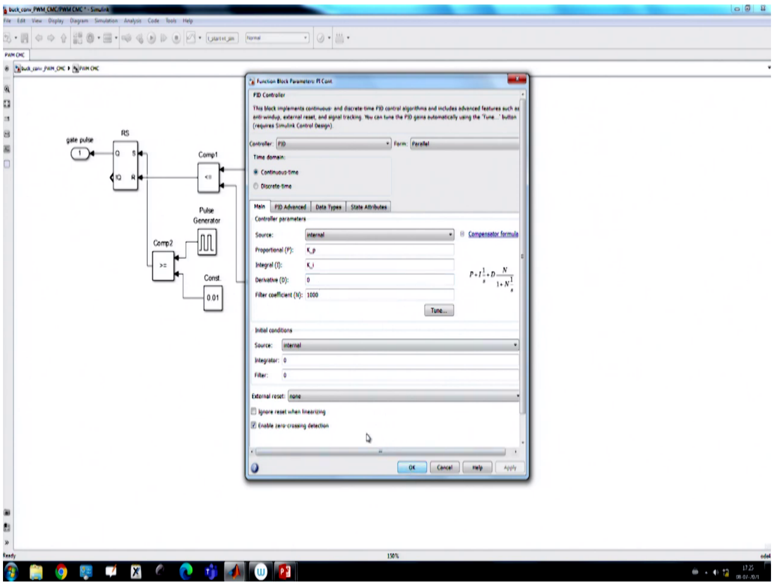


(Refer Slide Time: 21:24)



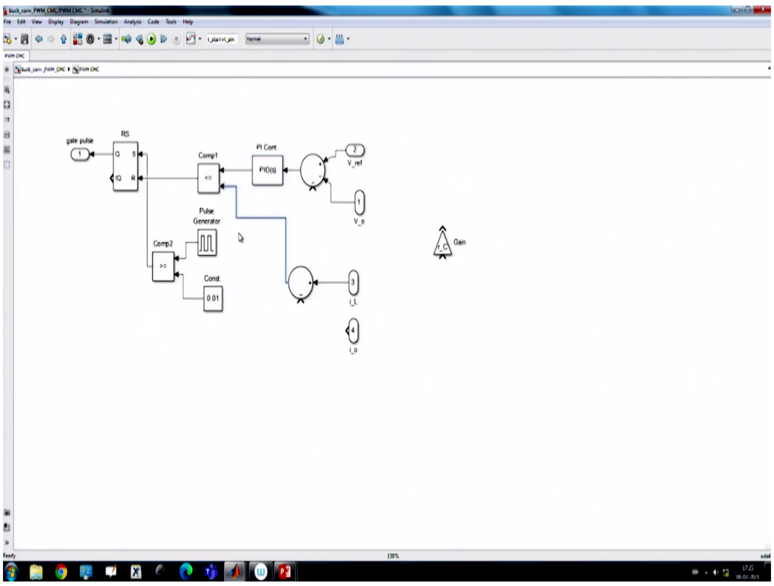
So, initially we want to consider no load current feedforward ok. So, let us remove this term everything is removed, ok. So, it is like an error voltage here, then there is a PID controller, but again I told the current mode control we do not in current mode control you do not need a PID controller just PI controller.

(Refer Slide Time: 21:43)



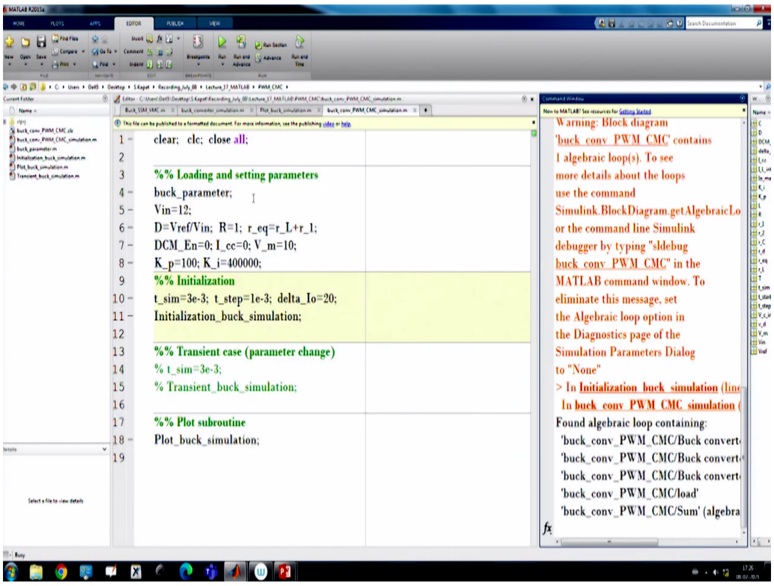
So, I kept the derivative gain to 0. So, you do not need to define anything here, ok. This is because this is a default block of PID controller. And, here I am using inductor current straight away here, though there is a summing block, but I am not making any changes here ok.

(Refer Slide Time: 21:59)



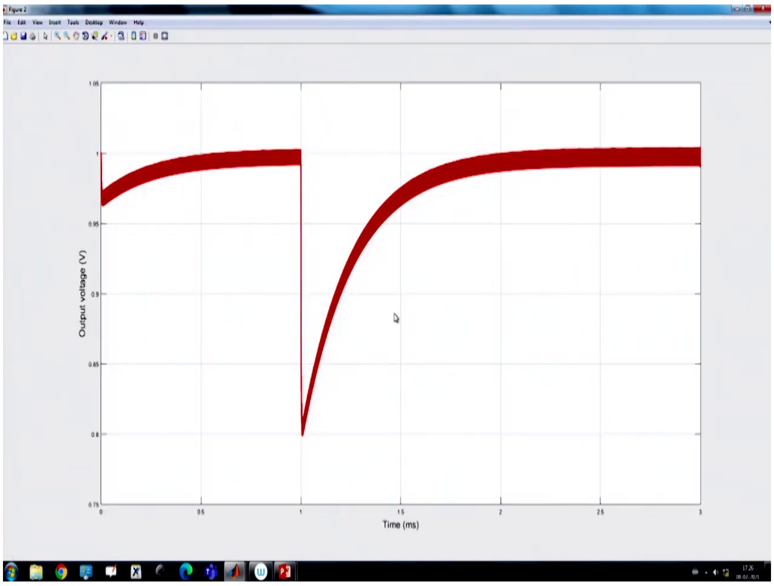
So, this is a current mode control implementation. And let us say, we are applying a load current of 20 Ampere. And, initially it is 1 volt, the reference voltage is set to 1 volt and input voltage is 12 volt, let us run it.

(Refer Slide Time: 22:11)



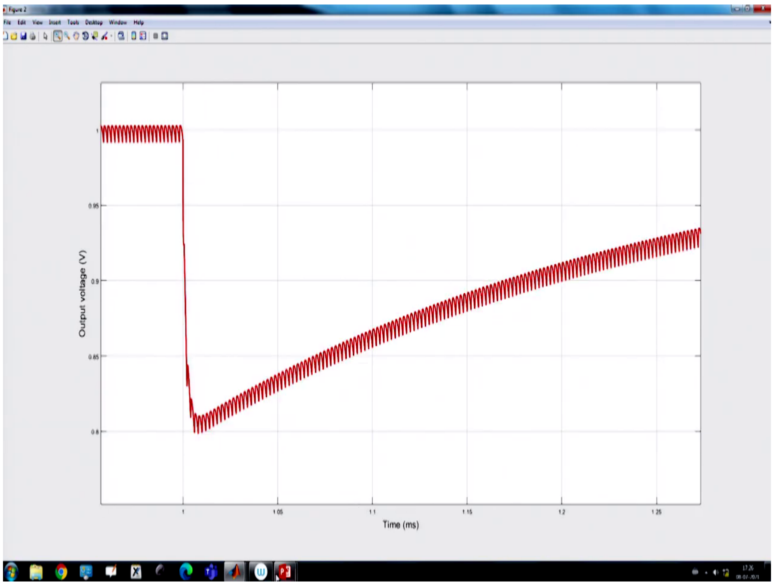
So, I am showing the load transient response of a current mode control ok.

(Refer Slide Time: 22:15)



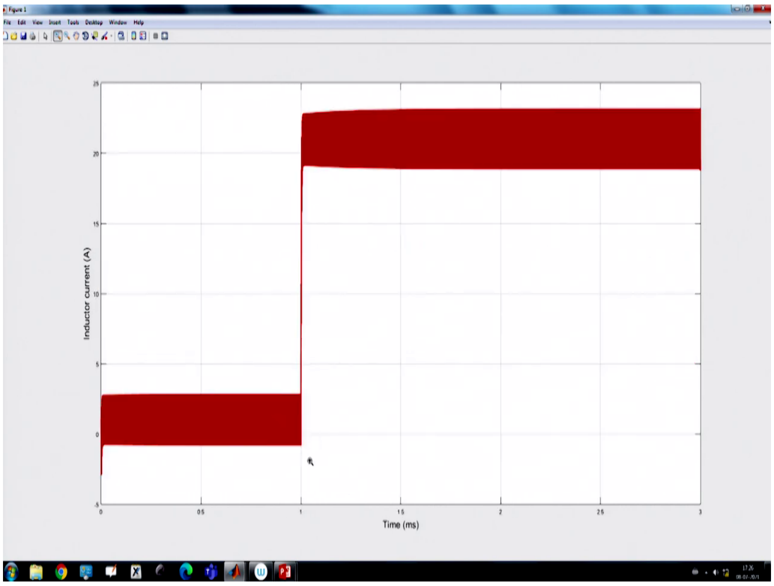
So, here.

(Refer Slide Time: 22:22)



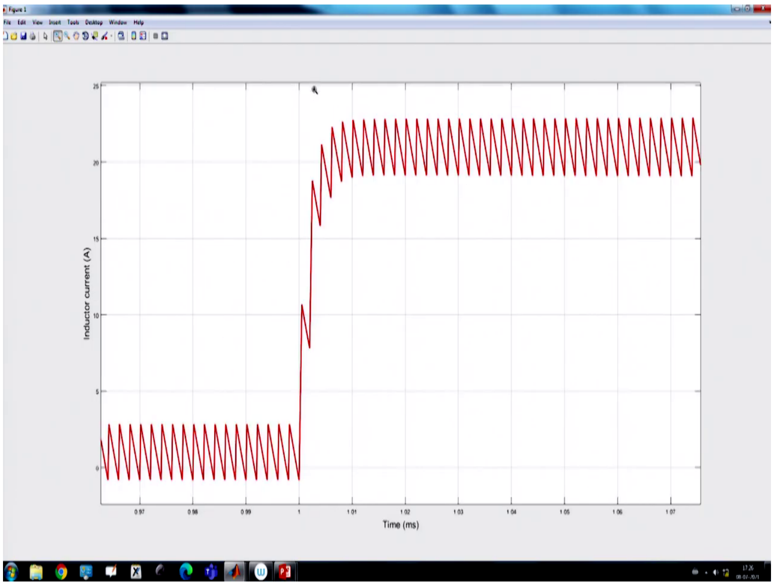
At this point we applied a 20 Ampere load step.

(Refer Slide Time: 22:24)



And, this is visible from the inductor current waveform.

(Refer Slide Time: 22:29)



Here, and initially it was 1 Ampere was the average current.

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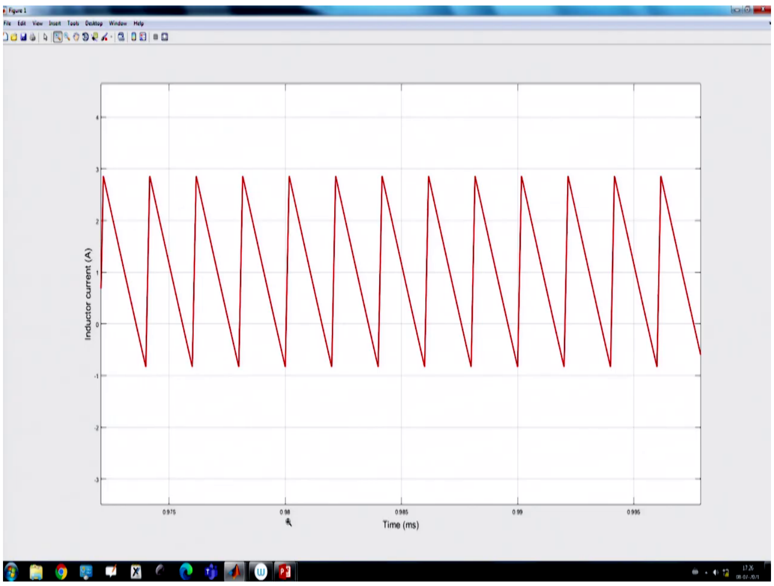

The average current was 1 Ampere.

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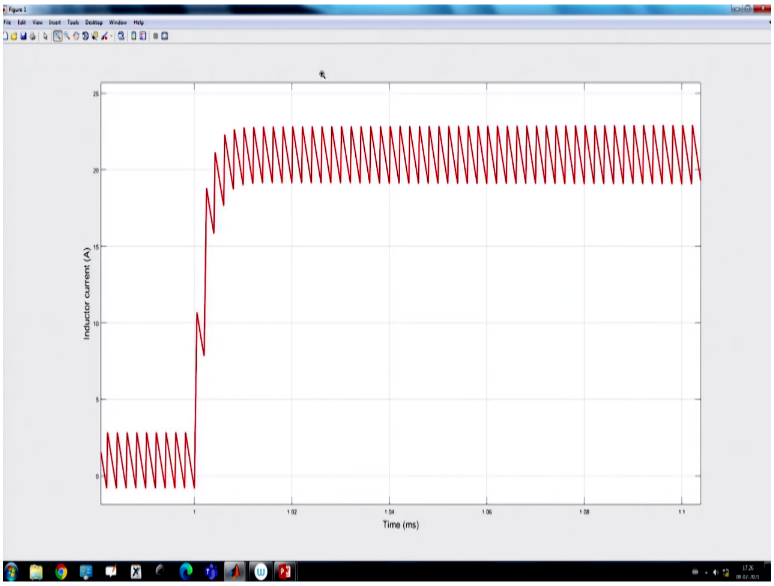
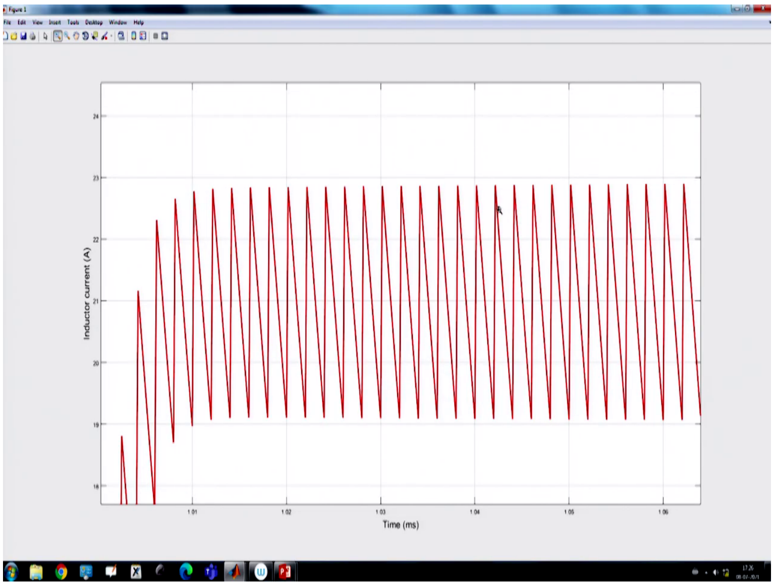


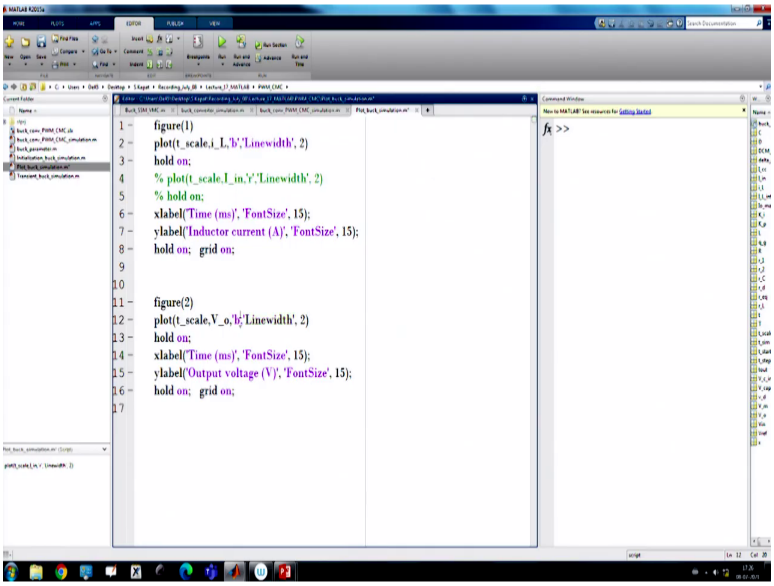
Now, we have applied a load step of 20 Ampere.

(Refer Slide Time: 22:37)



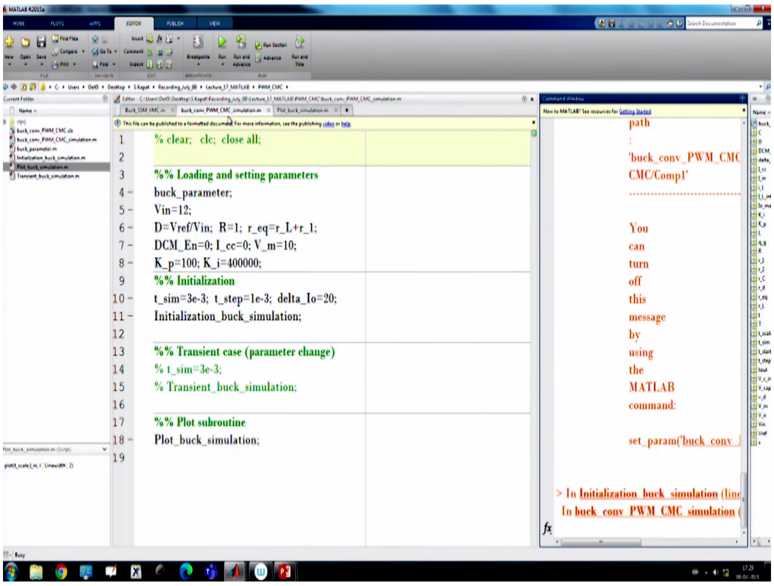
So, average current should be 21 Ampere and we are getting that ok. So, this is a load transient response using current mode control. Here, we have not used any feedforward action, ok.

(Refer Slide Time: 22:52)



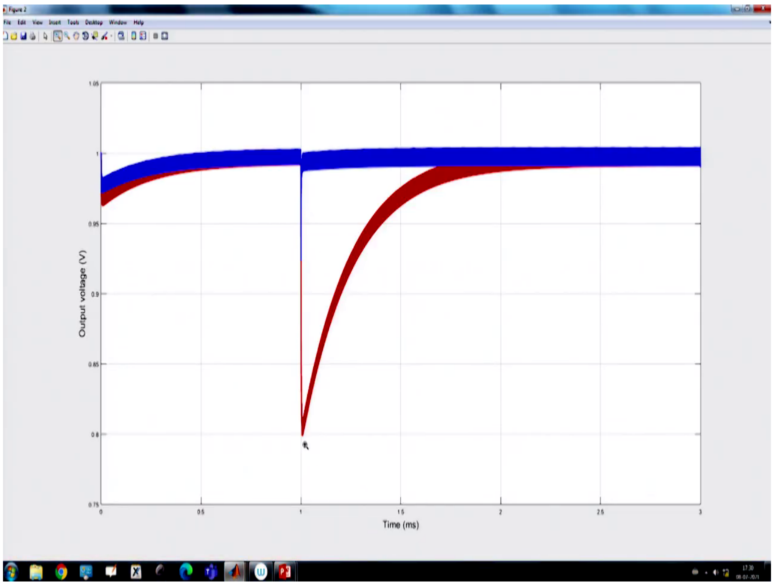
Next on top of that in this plot command, if you go to the plot command, I want to show the blue color trace with load current feedforward, ok.

(Refer Slide Time: 22:59)



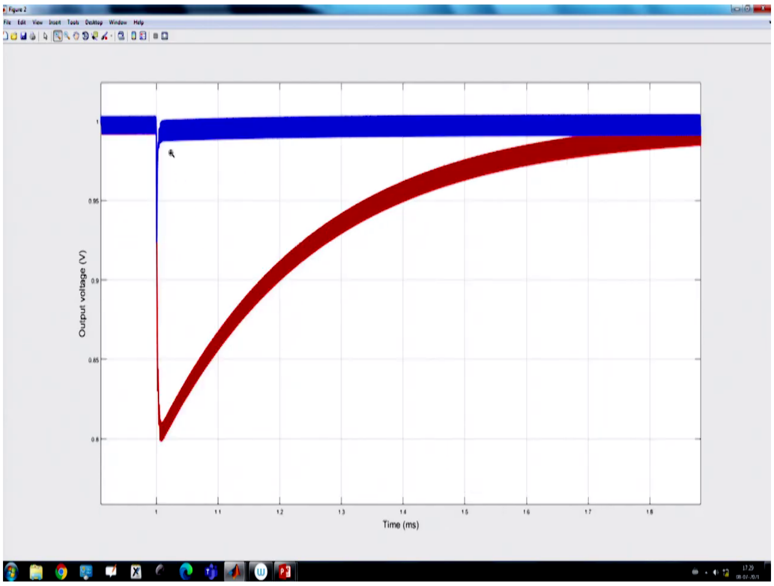
So now, we are I am showing you the scenario with load current feedforward, earlier it was without load current feedforward ok.

(Refer Slide Time: 23:08)

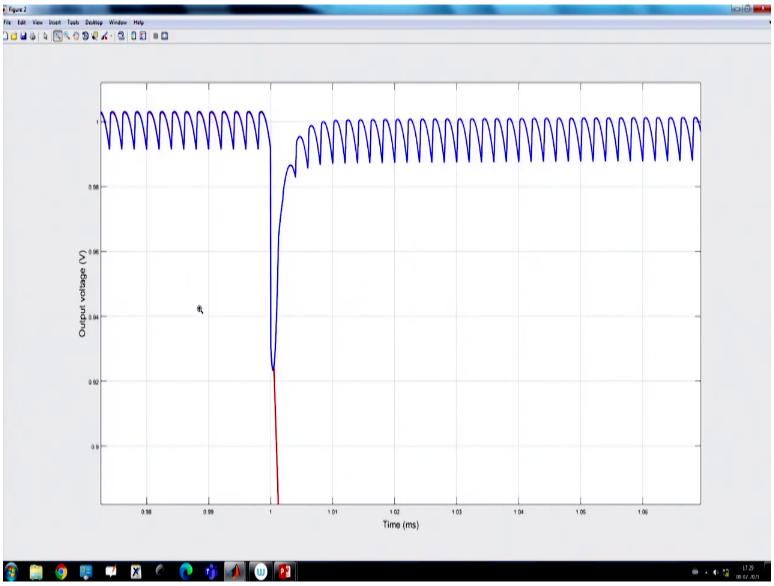


So now, you can see the transient performance is significantly improved.

(Refer Slide Time: 23:13)

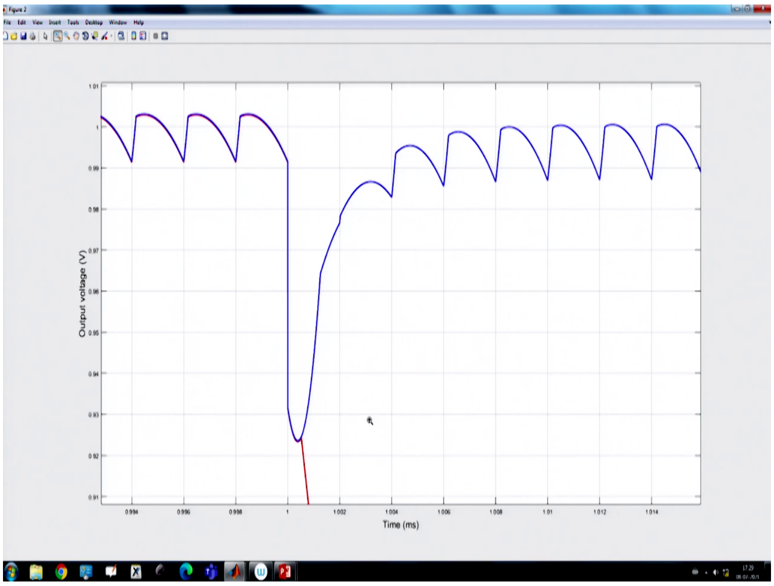


(Refer Slide Time: 23:15)



Is a very fast transient response using load current feedforward.

(Refer Slide Time: 23:17)



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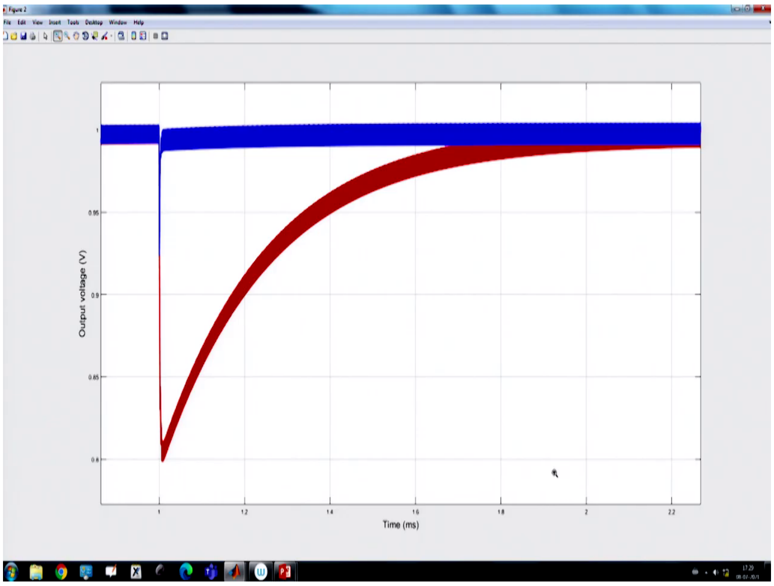
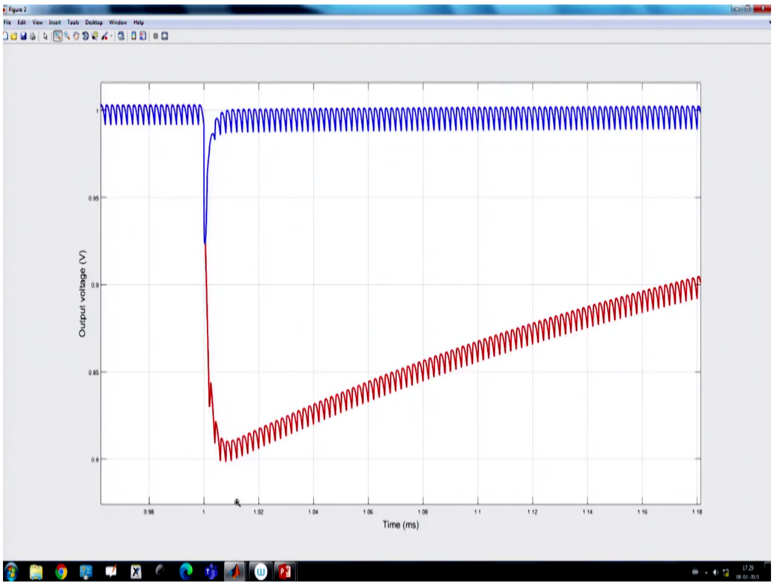


You know it can reach like almost within a few cycles right.

(Refer Slide Time: 23:25)



Few cycle it reaches, steady state.

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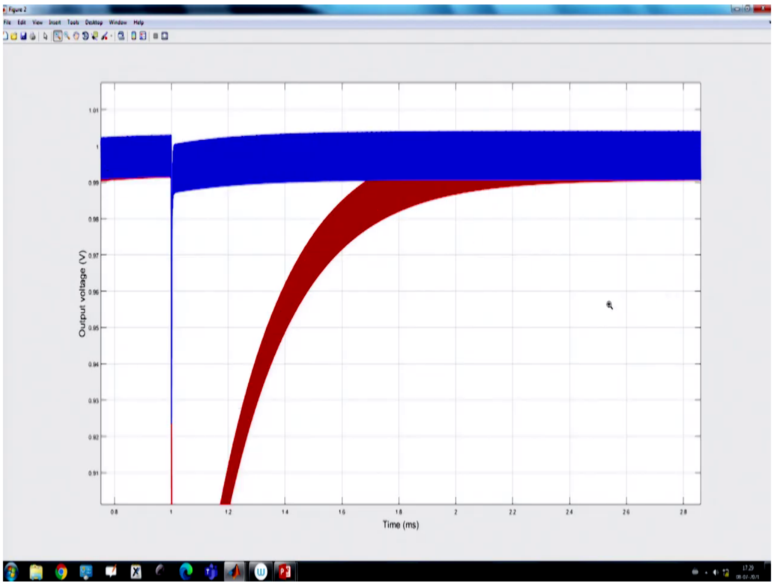
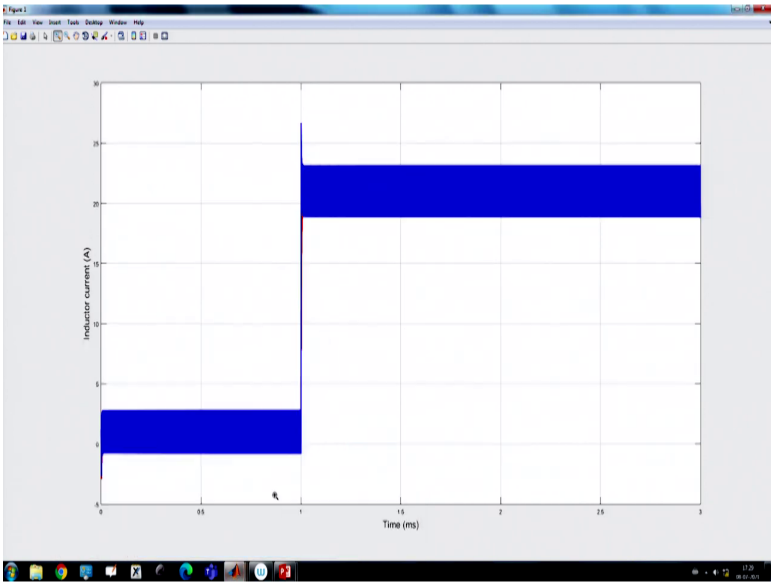


So, you can achieve very fast transient performance.

(Refer Slide Time: 23:35)



And, if you go to the inductor current waveform.

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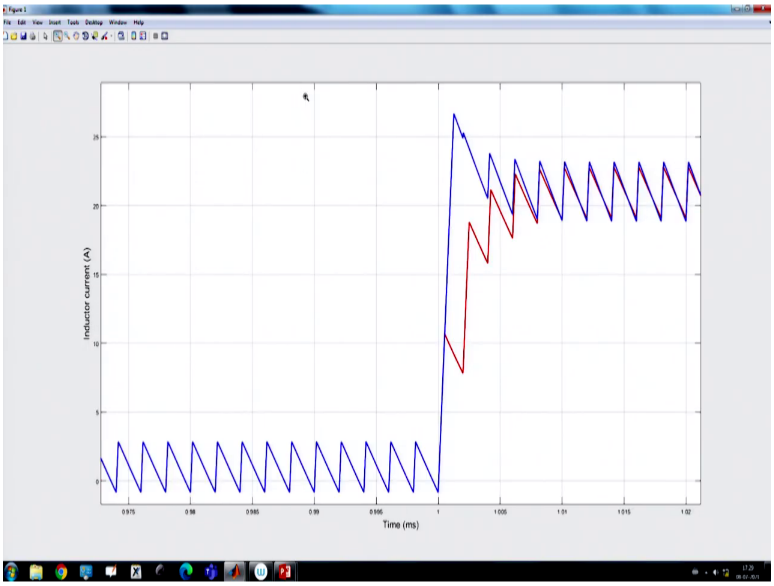

You can see very closely if you look.

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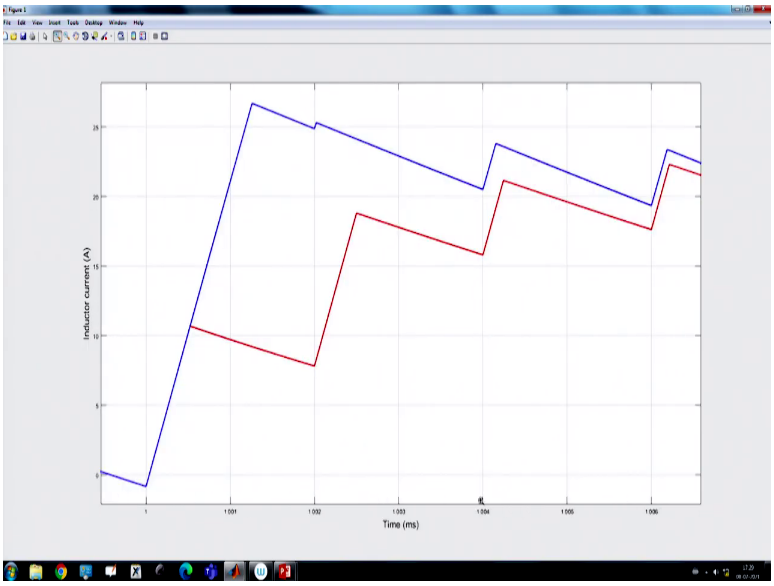

It respond very fast, but average 21.

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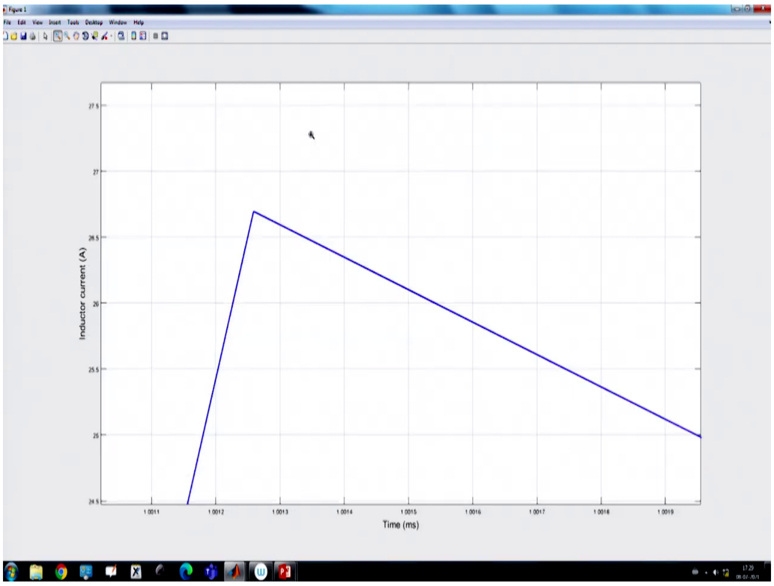

But it goes around you know 26.5 above that.

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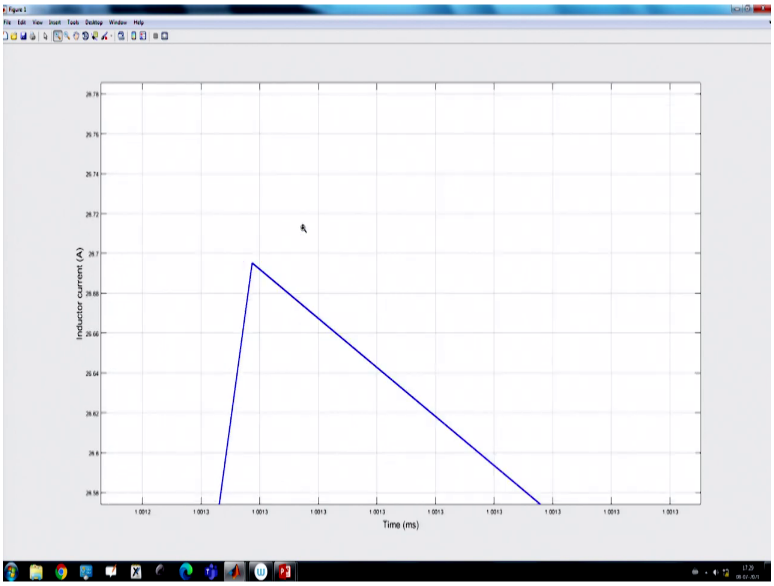
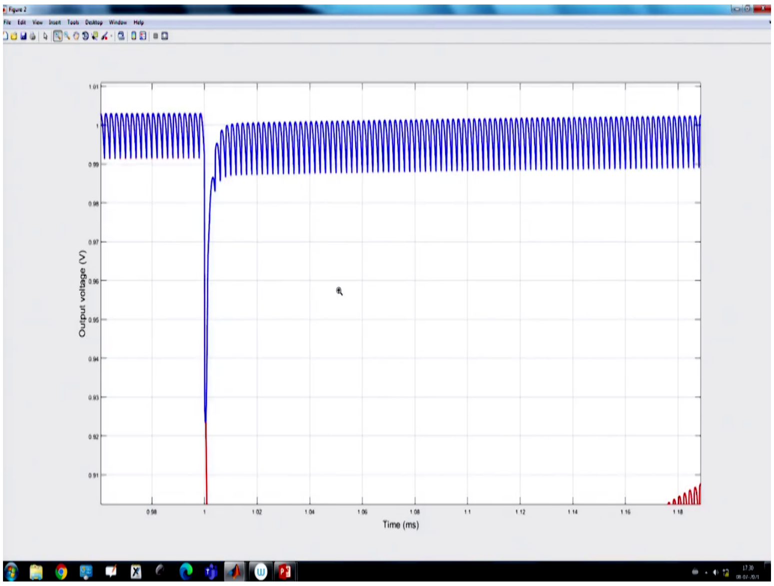


That peak current 26.7, which may be too large, but that is fine.

(Refer Slide Time: 24:00)



Now, my next question is that.

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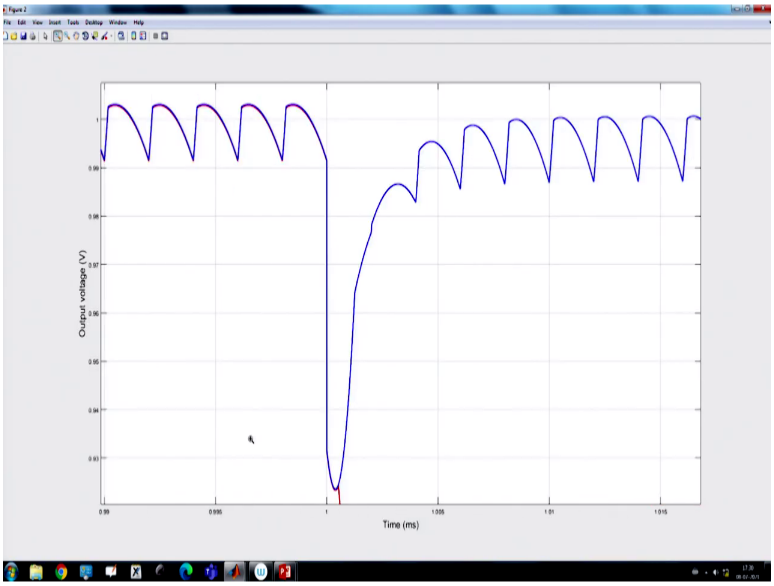
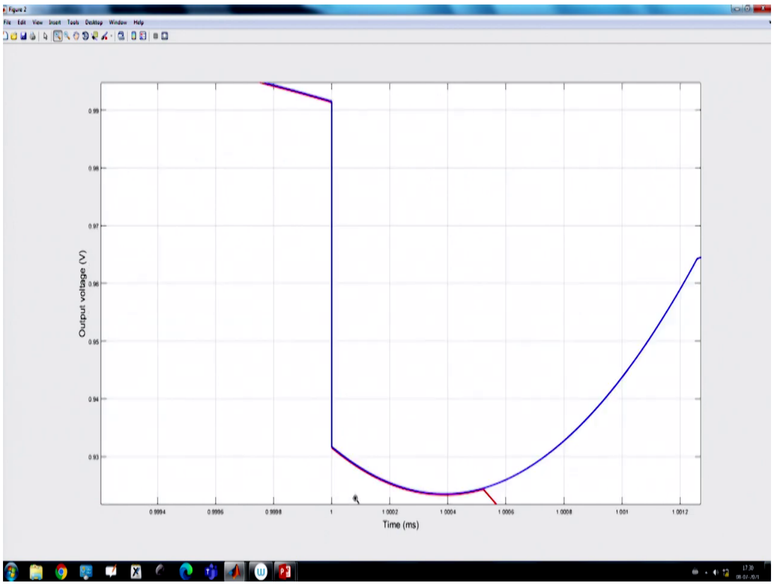


So, you can see you cannot avoid this jump, because, there is a jump discrete jump.

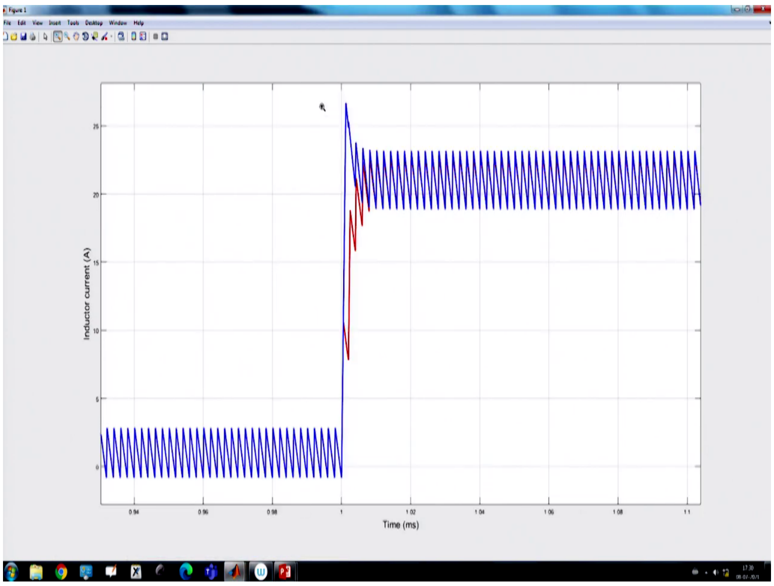
(Refer Slide Time: 24:05)



And that is due to the ESR that will see. That means, this jump is ESR multiplied by the load step or, in fact, it is the equivalent between ESR and register load resistance. And, whenever you will do impedance analysis will check that, but this drop is unavoidable, that will happen.

Now, my question is that if this drop is unavoidable. Can we keep the output voltage here rather than going back to the original 1 volt? Why do we need?

(Refer Slide Time: 24:38)



Because this will unnecessarily require a large overshoot as well. That means we will consider the third option.

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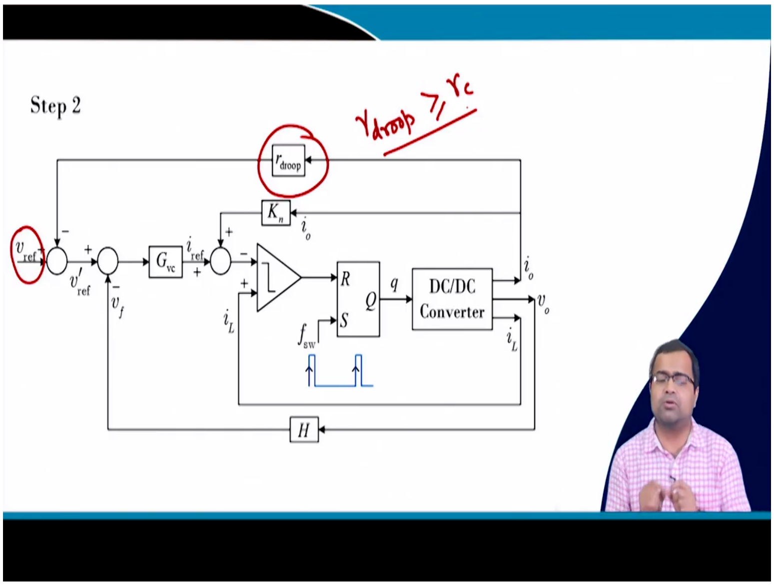

Which is now we are adding a droop action, droop; where we are trying to adjust the reference voltage by introducing a droop action, which actually creates a drop when there is a load step transient.

So, that, but now I want to consider this r droop because this droop should be greater than equal to r c that will see in the impedance analysis. So, we will see r c is the ESR; that means, this ESR drop is unavailable. So, you should not keep a droop value smaller than ESR, ok.

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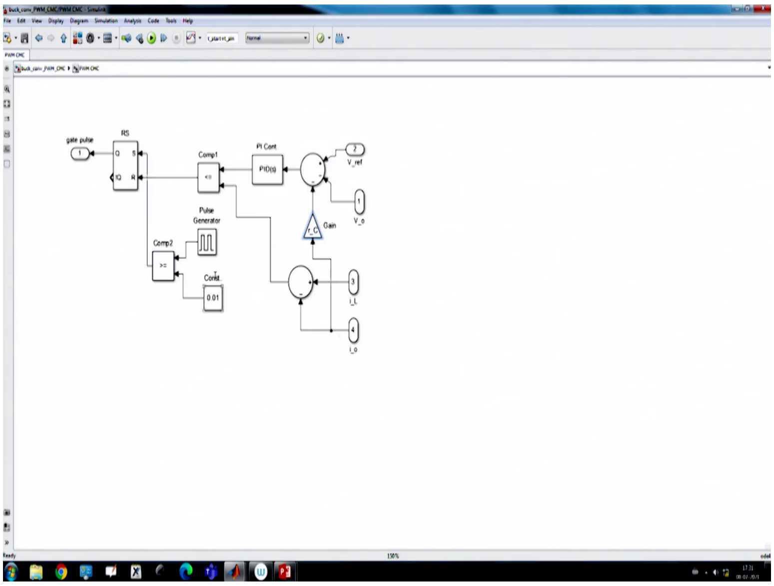

Now, let us go to the simulation and check for the third condition which is here. I put here, a droop action and it is connected to the load current, ok.

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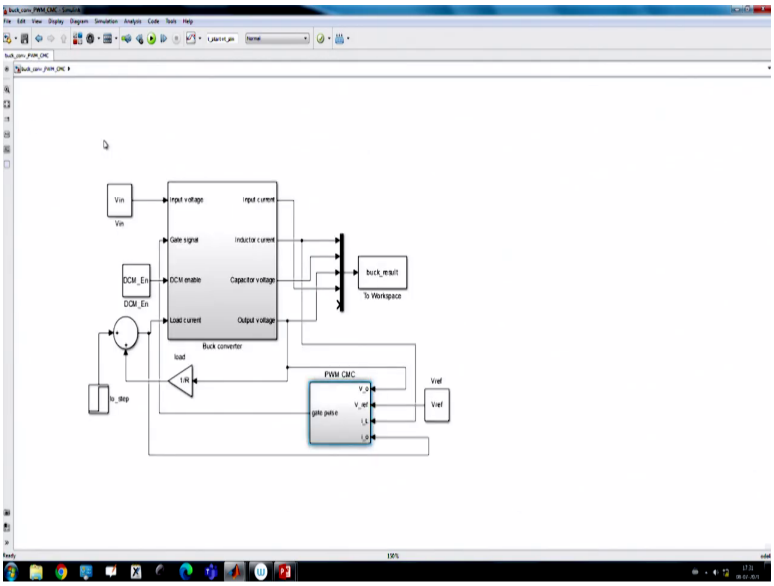

Now, with this.

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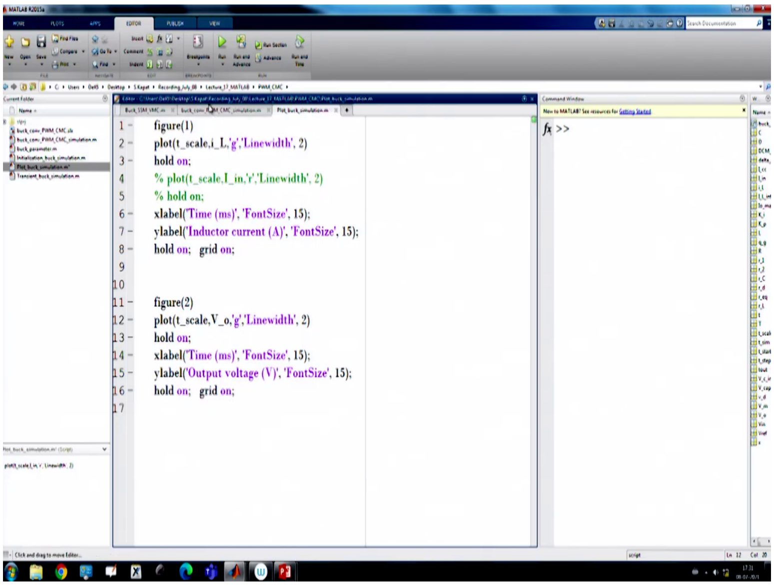

I want to simulate and plot; I want to create a green waveform ok, green and run the simulation again.

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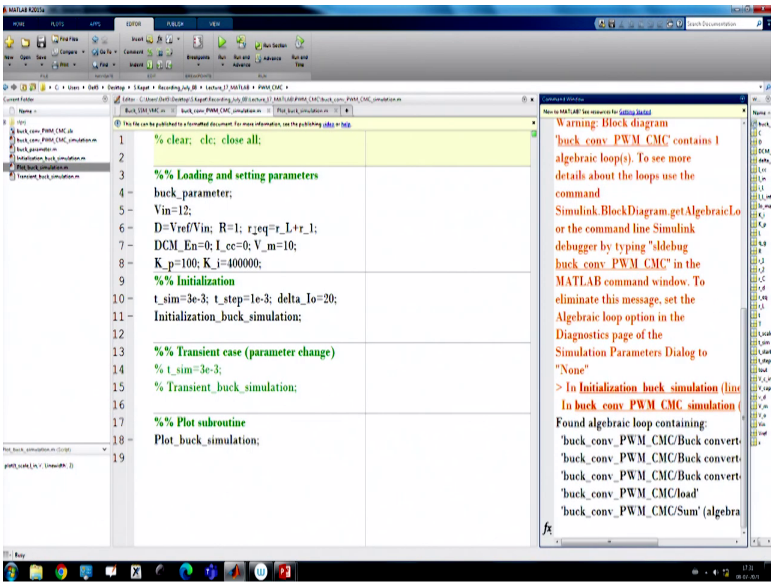

This is with droop control ok. So, here I will show you; that means, there is the reference voltage which is getting adjusted.

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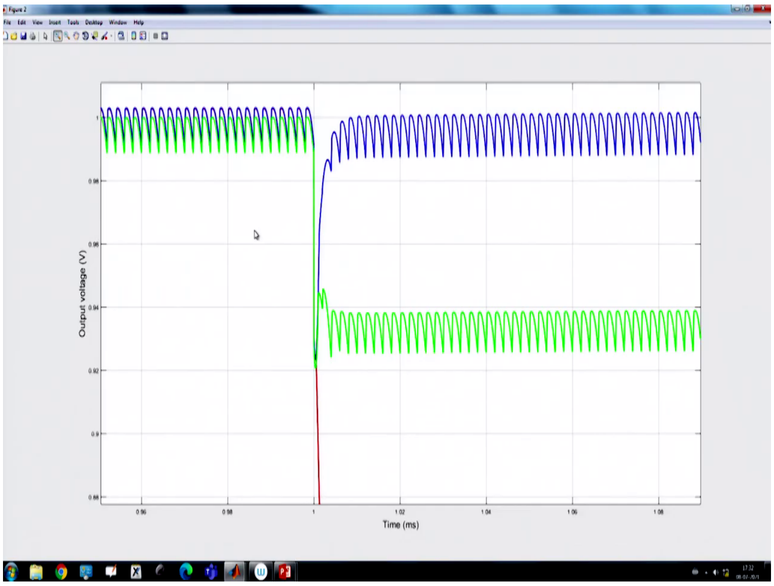

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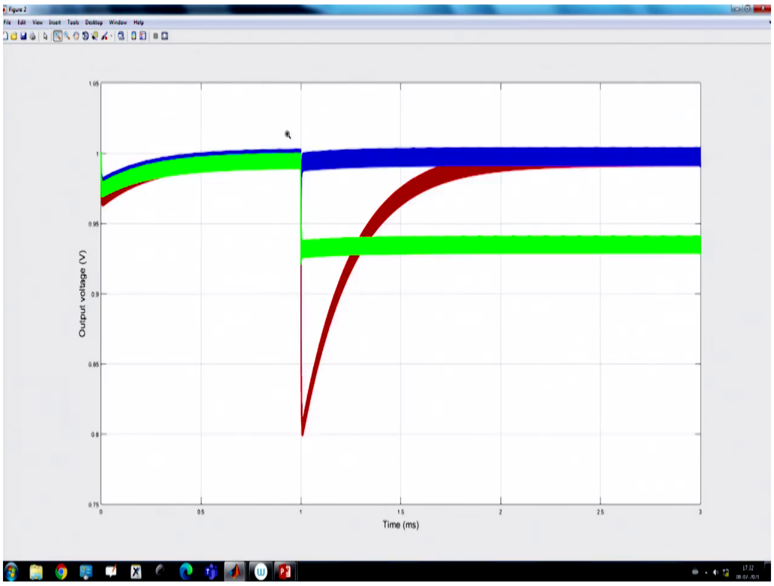

So, you will see one interesting fact.

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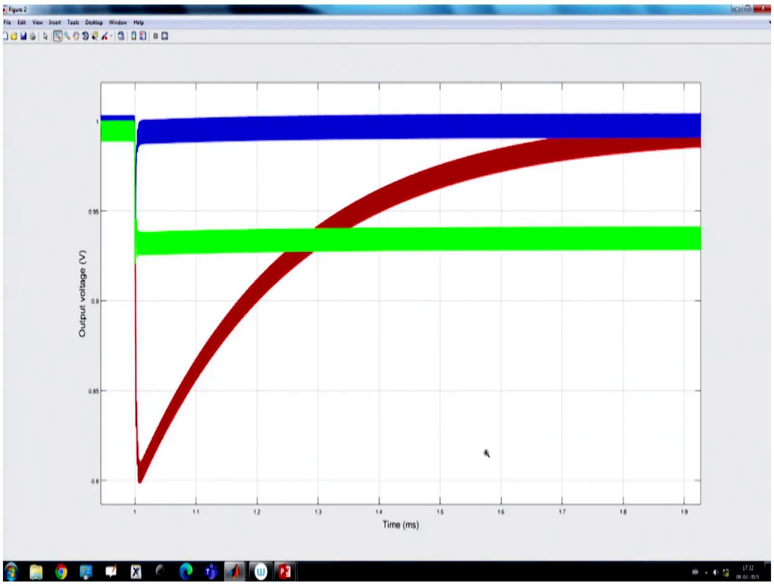

In the third case in the green, the output voltage is getting settled right at the jump point.

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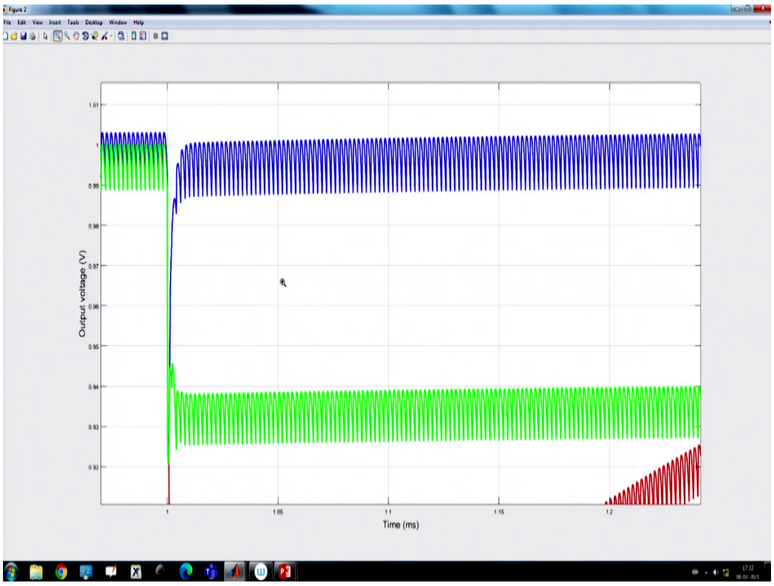

Because, there is a jump in the output voltage.

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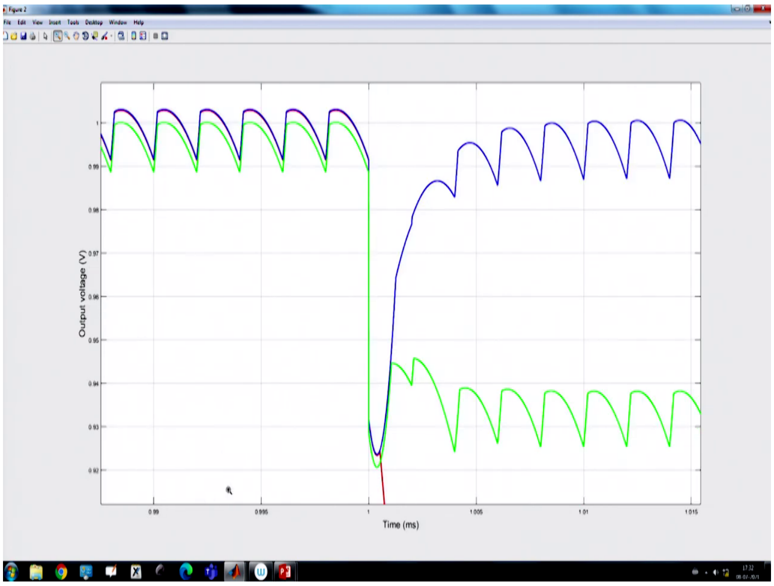

And that means, up to jump is up to here. So, I have set the new reference voltage to be here; it is getting regulated here.

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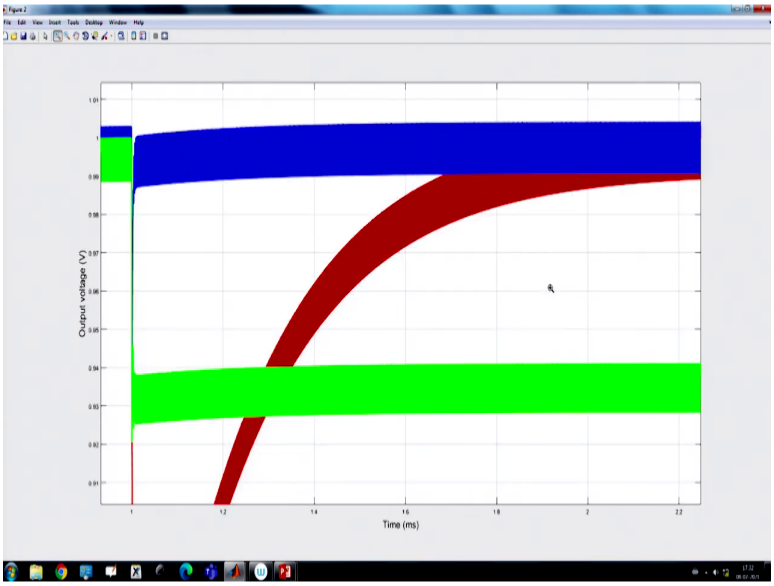

That means, I can get the reference voltage right there.

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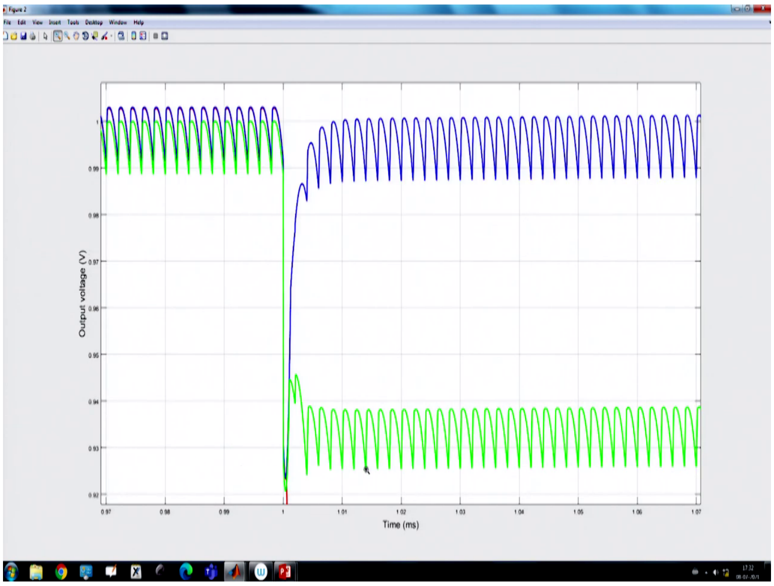

And, you can see as if there is no transient effect, it is almost immediately settling. That means, your output impedance, you know we discuss output impedance of a practical source in lecture number 13, where we consider one inductor and capacitor. So, we cannot avoid the output impedance of a DC-DC converter, but we check two things.

There one is the DC equivalent another is the AC output impedance. Because of AC output impedance, we are getting overshoot undershoot here. But here we are intentionally increasing emulating, not putting a physical resistance by means of control. By droop action, we are emulating that we are introducing a DC output impedance, which is same as the resist ESR of the resistance capacitor.

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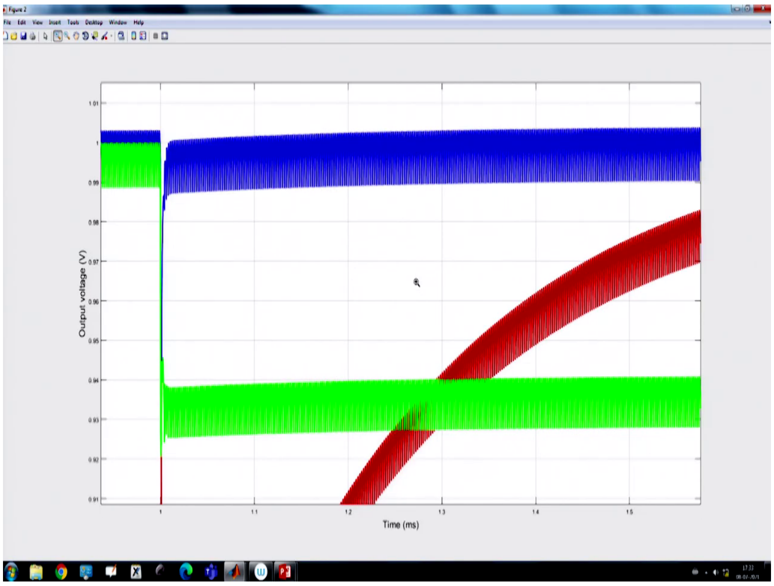

And, if you do that we can get the output impedance almost independent of frequency.

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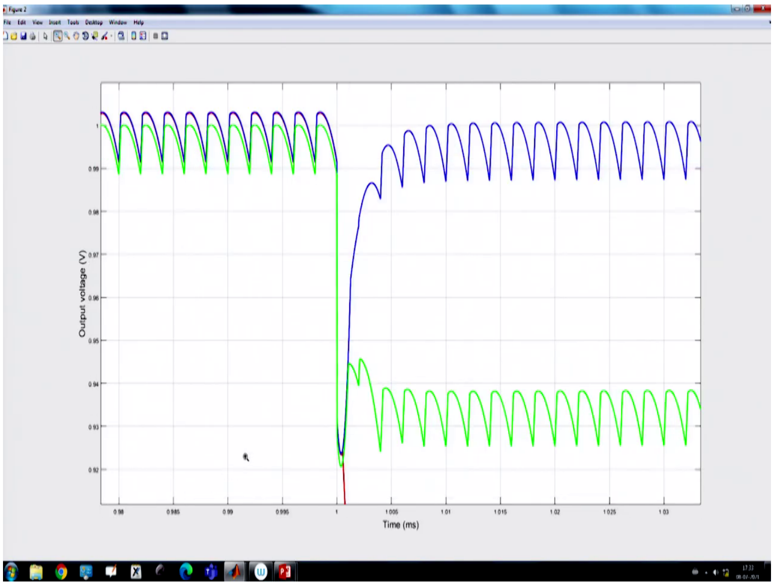

Because, it does not actually seem to have any transient effect, ok.

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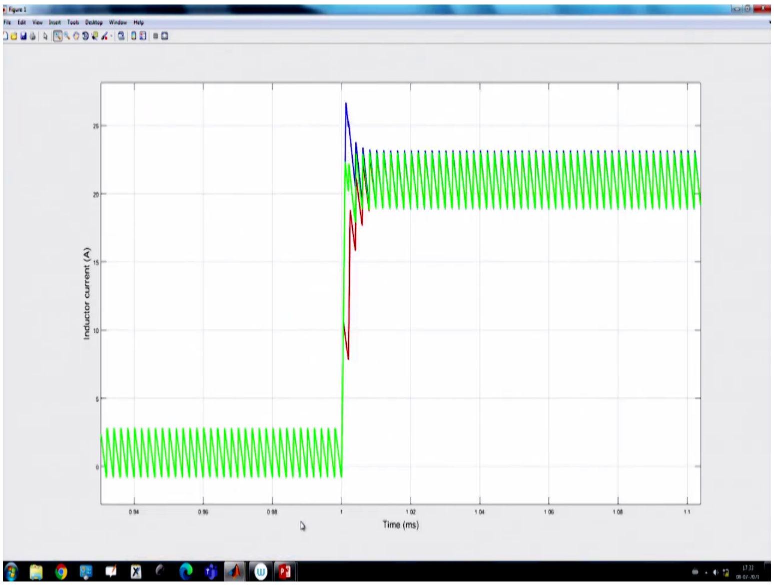

And, if you go to the current waveform.

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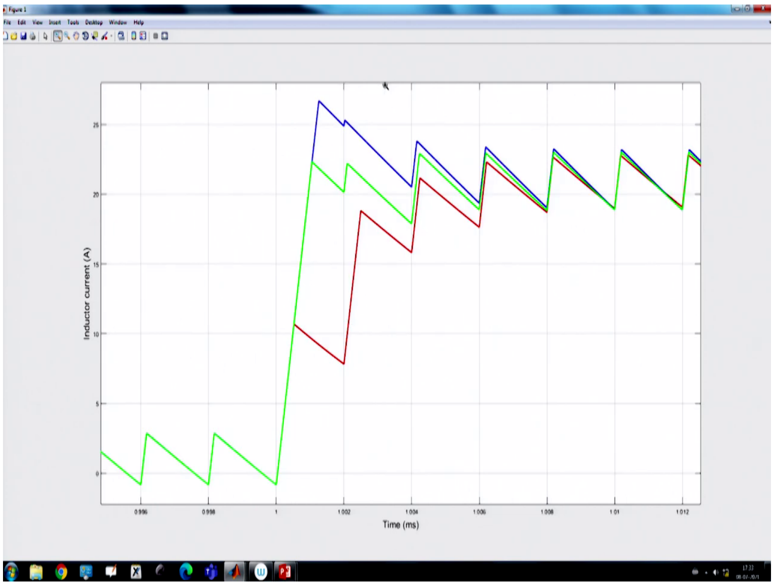

The current is increasing and staying there; no overshoot is there. And, another thing is that there is no current overshoot that is a beautiful thing.

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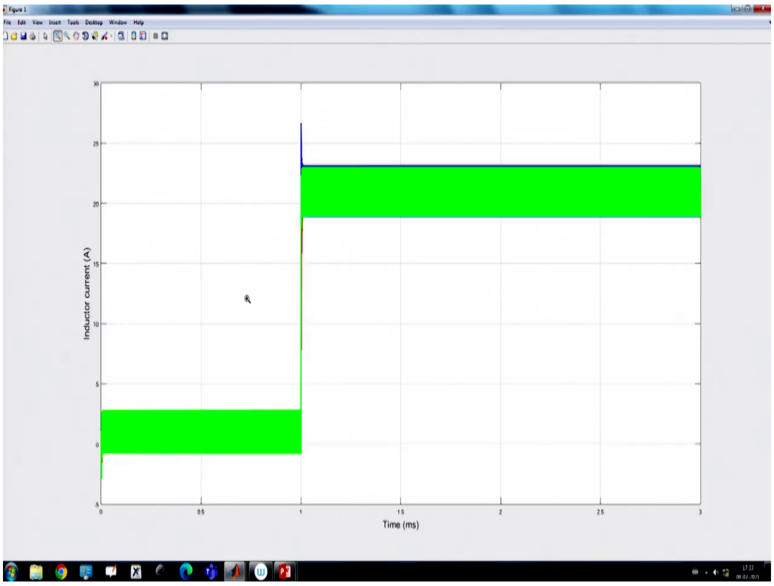

So, this characteristic is in the context of a power converter.

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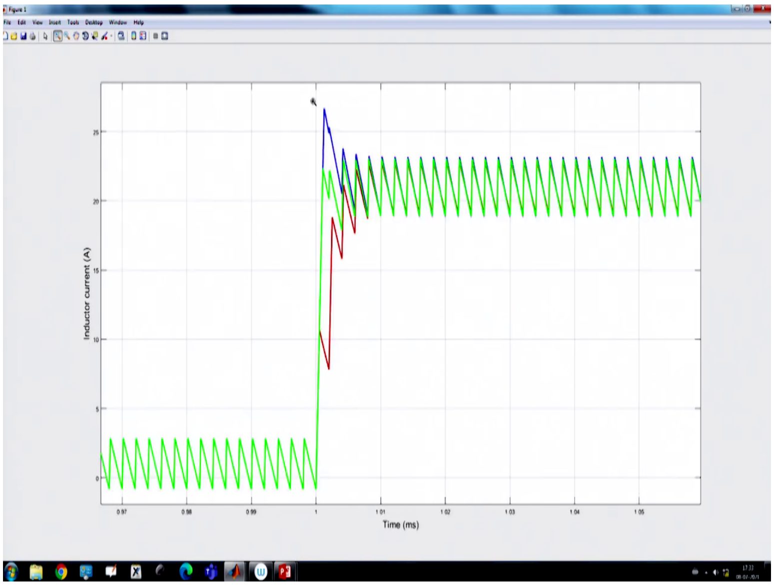

This is known as the adaptive voltage positioning.

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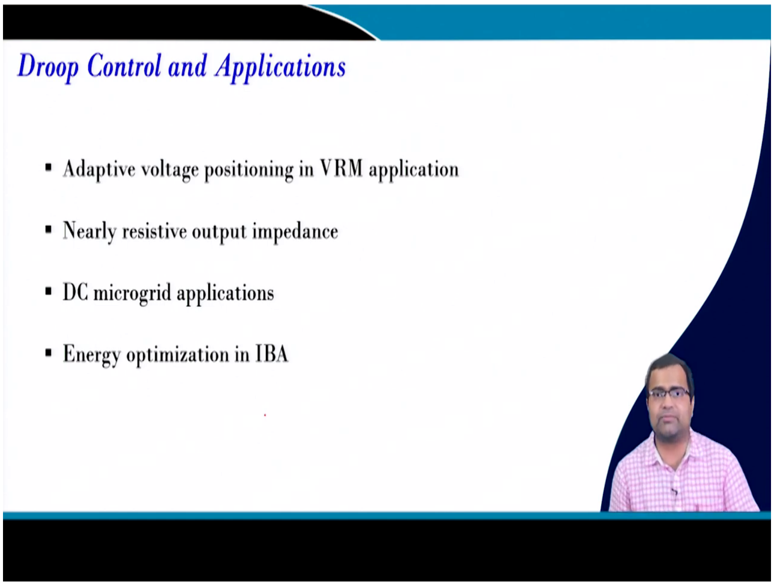

For this is particularly used when you are talking about low voltage high current application; when the current can be even tens of 100s of Ampere ok. And, if you if there is a 100 Ampere load step chain and if you there will be a jump due to the ESR and if it again needs to go back that may take lower more time. And, even if you apply a high gain, the current overshoot can be pretty high.

So, this process can cut down the current overshoot and it will also remove the transient effect, but the penalty it will shift the DC regulation point a little bit, but if it is within the acceptable limit, then it should be ok. And, we can reduce the effective ESR by putting multiple capacitors in the parallel bank in the output. We can also reduce the droop.

So, this will behave like a nearly resistive output impedance and we will see in that when you do impedance analysis under current mode control. And, this technique is also used in microgrid only the name is different; there we called as a droop control. And, we intentionally reduce the voltage based on the current requirement from let us say if it is a solar panel or any other supply. So, we do this droop control, ok. Then, we can also do energy optimization by means of this.

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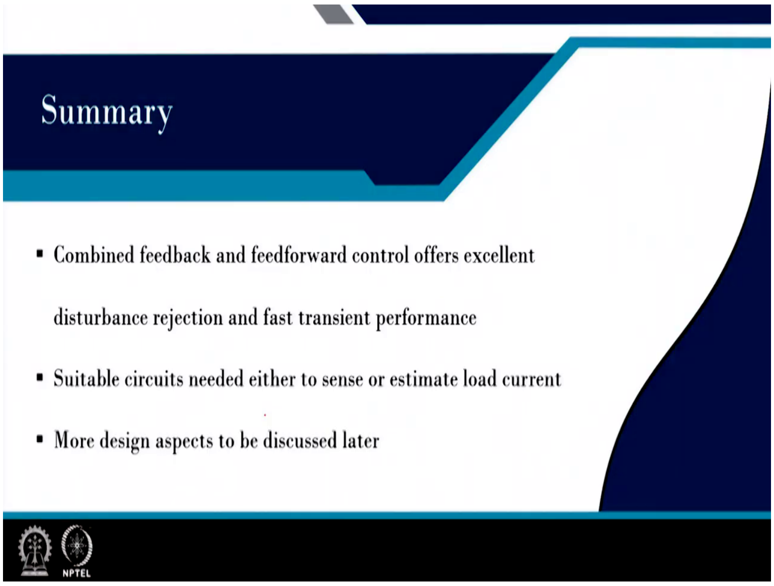

So, with this you know we have discussed combine feedback and feedforward control and that offer excellent performance. For voltage mode control, if we apply a supply voltage you know feedforward, we can get very good audio susceptibility. In load you know, for current mode control if we apply a load current feedforward we can significantly improve the transient response and if we apply a droop control, we can almost cut down and the output impedance will see like a resistive one.

But sensing load current is a difficult task. In case of droop control in microgrid application, the transient performance requirement is not significant. So, in that case, the average current can be obtained, because in buck converter average inductor current is same as the load current that can be obtained from the average value of the inductor. That means you do not need to sense the load current and you can do the droop control.

But, in low voltage high current where the transient performance requirement is very fast, there the inductor current itself will take some time to slew up. So, you may know you will not get the load feedforward from the inductor average value. So, you may need to either sense load current in buck converter we can take, we can use a derivative action or in digital control, we can do a lot of I mean you can do estimation, and we can very you know effectively or very accurately estimate the load information.

In fact, the present processor actually the power supply in digitally controlled converter, there is something called power management bus, PM bus, where there is a data as well as the clock communication. So, if you communicate with the processor and if you understand the task requirement, in fact, you can estimate the load current. That information can be used to implement such an algorithm. So, more design aspect will be discussed later. And with this I want to finish it here.

Thank you very much.