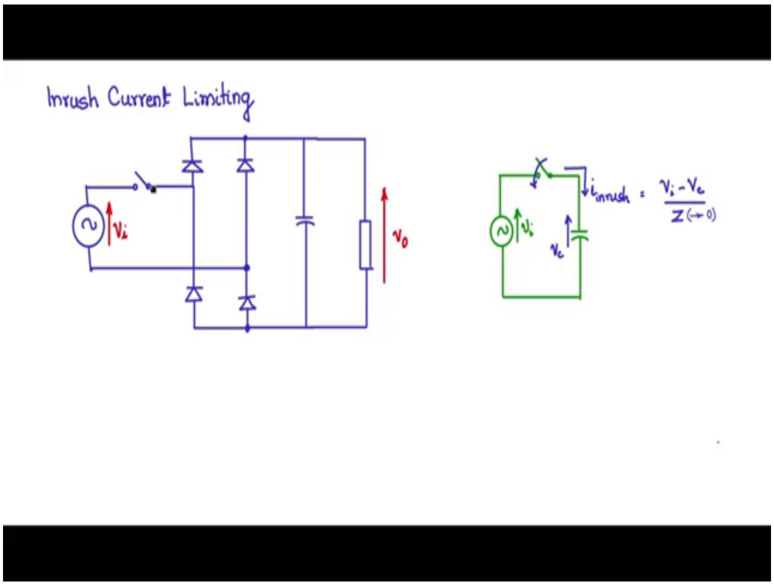
Fundamentals of Power Electronics
Prof. L. Umanand
Department of Electronics Systems Engineering
Indian Institute of Science, Bengaluru

Lecture - 17
Inrush current limiting - intro

(Refer Slide Time: 00:27)



Let us now discuss a very important topic and that is Inrush Current Limiting in Rectifier Diode Capacitor Filter Circuit. This inrush current limiting is a very serious problem in the rectifier diode capacitor filter circuit. So, what it basically does is that in the circuit as we see here you have the source connected through a switch and through a diode bridge rectifier like this when you have a capacitor here and this is the V naught across the load and the load may be resistive or any other power supply itself.

And the problem here is that the source the current through from the source passes through the switch during on condition which is a very low resistance, passes through the diodes in the forward bias condition which is again very low forward resistance and passes through the capacitance and back through this diode and the source. Likewise, in the negative direction also it takes the alternative path.

The problem here is that you have very low negligible impedance in the path the current flow path for the current flow from the source to the capacitor, to charge it up. So, at the time of startup when you want to switching on the switch, you can expect a very large inrush current to be drawn from the source and this large inrush current can blow up these diodes or even the capacitor. And we have designed all these diodes and capacitor to operate only in the steady state condition.

So, this implies that even though the diodes have diodes and the capacitors have been designed for steady state operation the moment you switch on the circuit, by switching on the switch the components will blow and the circuit will not operate. So, every time you switch on the circuit there will be components blowing. So, how do we overcome this problem of inrush current limiting? Now, that is the discussion now that we will see.

You can now consider the source V i connected through the switch flowing through the capacitance and connect them this fashion. So, the source V i having a voltage V i and if you switch on the switch close the switch you expect a current to flow through this path and this at the time of startup is called the inrush current and this can be very very high.

Why will it be very very high? Now, let us say that you have V c as the variable indicating the voltage across the capacitance here. So, inrush current is difference in this potentials, so that is V i minus V c divided by whatever is the path impedance. Now, the path impedance is comprised of the impedance of the source which will be very low the importance of this closed switch which again will be very very low, here are the capacitance again low and track impedance wire impedance and so on. So, therefore, the impedance in this path is very very low and that Z is tending to 0.

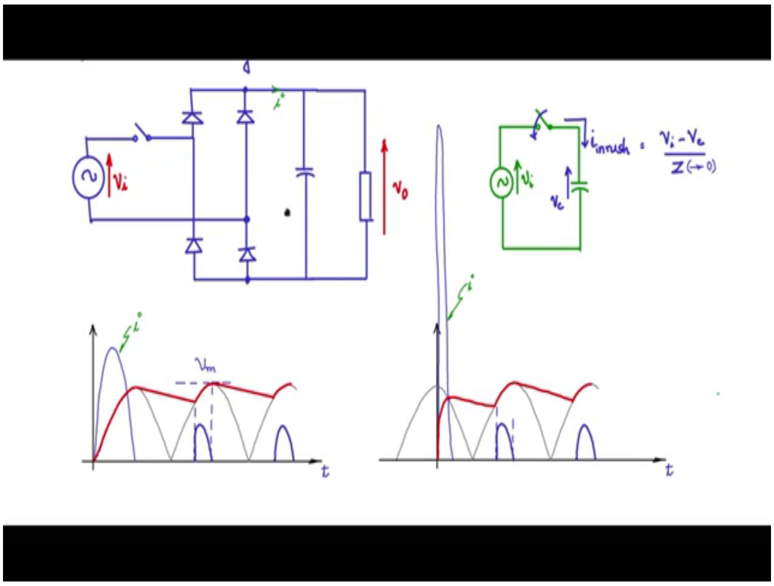
So, let us imagine a situation where when you are starting. So, at the time of starting V c is 0, so this is 0. And the inrush current is given by V i by Z and Z is very very low. And as chance may have it at the time of switching this on V i worst case possible can be V i peak, the max possible value in the sine wave. So, that value divided by Z can be a very very large value, can be 1000s of amps and this is 1000s of amps these diodes are not designed for and they will blow up. So, every time you switch this on, this diodes will blow up or the capacitor will blow up and this circuit will not function at all.

We have designed these diodes and capacitor to function in this steady state, but we are not able to take the circuit into the steady state because of this inrush current problem. Why should the circuit operate during the steady state? So, at the steady state the capacitor is fully charged in this; this is fully charged. So, this is close to V i peak. So, V i peak minus V c which is close to V i peak could be a delta V divided by a small value divided by this Z will give you significantly lesser inrush current. And that value is what we have design these diodes for, the capacitor for to handle these currents.

So, in the absence of this charge here you can expect a very large inrush. And how do we make the transition from the switch on transition dynamics to the steady state dynamics where these components can handle the current, now that is where we need to put some circuits here which will make the transition, startup transition and then hand the bottom over to the steady state portion and the steady state portion the diodes and the capacitance will behave as we have discussed in the last week.

So, let us now see what circuits we need to interpose here to make the circuit operate even during startup and transit nicely and smoothly into the steady state operating mode.

(Refer Slide Time: 06:55)



Now, let us see what happens to the wave shape when the switch is closed. So, let us draw the x and y axes and let us say that this is the rectified input sine wave, it has an amplitude of V m. So, it is basically V m sin omega t and we are taking a benign case, where at the time when this switch is being closed that is t equal to 0, the input wave is at 0 and it rises in a sin fashion. So, you are synchronizing the closing of the switch with 0. Under such conditions what happens? So, this is the t axis and you will see that there is a large inrush current and that is corresponding to this i here, I will mark it here.

So, large inrush current here and what happens to the voltage wave form, output voltage wave form? This voltage wave form will rise here along with V i up to this point and then the V i is falling the diodes are reverse biased, then this will start going down in this fashion depending upon this load. And then again when V i crosses and forward biases the diode here you will see that it charges the voltage follows the input wave shape, so on this repeats. So, here actually you have reach steady state. So, here there will be a current flow as we have seen in the previous modules.

So, this will correspond to the charge state the capacitance. So, you will see that this peak amplitude is correspondingly smaller compared to the starting peak, ok. Now, this is a benign case where the switch turn on is synchronized with the 0 crossing of the input which will not happen in most cases, it will not happen in a particular situation. When you turn on it may so happen that the input is at its peak at the worst case condition and what happens.

Now, consider the worst case condition where at the time of switch on of the switch, switch on of the switch, it so happens that the input voltage is at its peak value the V m is at this point suppose sine wave. So, this could happen this the worst case condition if this happens what will be the peak inrush current.

The steady state portion there is no change there will be similar to what it was here. During this point it is V m and it is V m by impedance Z there V c is 0 that is a charge on the capacitor is 0 therefore, no voltage. So, you will have very large overshoot I just want to show the relative magnitude will be something like that will be much higher than what would be for a synchronized switching where V i starts from 0. So, this could be a very large value. It could go to 1000s of amps.

So, this is the current here and the capacitor voltage quickly builds up to this value and then the diode cuts off and then the steady state starts. So, you see that it is during this time the entire problem occurs and during this time itself the diodes will blow and you will not be able to take it to the steady state. You can in fact, verify this by simulation. In the previous modules, I have shown you the simulation of rectifier circuits in ngspice, you could probably get some insight by doing some simulation on that. Probably I will show you a quick example.