**Fundamentals of Power Electronics**
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**Lecture – 21**
**Inrush current limiting – MOSFET solution**

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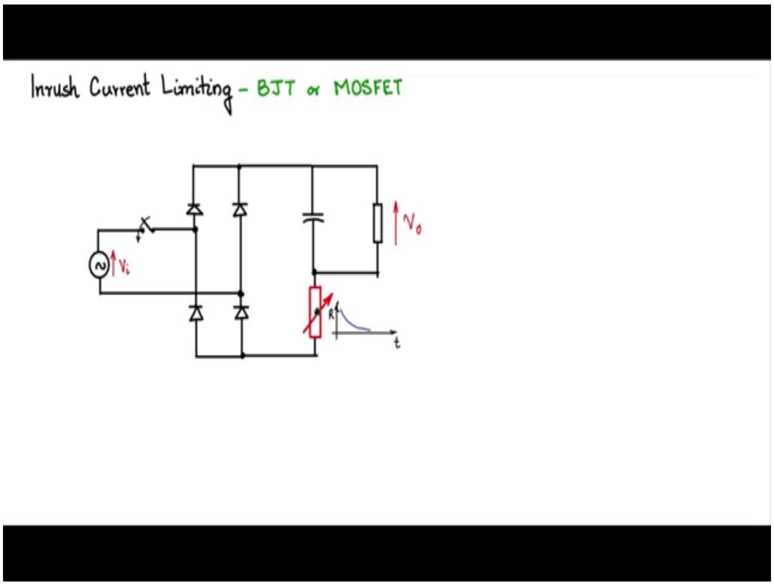


There is another Inrush current limiting method that we will discuss, and that he is by using an active semiconductor device like the BJT bipolar junction transistor or the metal oxide semiconductor effect. The circuit description will be like this, we see that the source through a switch is connected to the diode bridge rectifier output of which goes to ac filter like this and connected to the load then finally, is connected in this fashion. So, this is our regular rectifier diode bridge capacitor filter circuit, the switch. So, we have t equal to 0 the switch will be closing an a Voltage V i will be applied, this is V naught. So, this is our regular circuit.

So, what we will do is here we will remove this conductor and replace that with a resistor; a variable resistor. So, here two you will get the same resistor effect where it will limit the current. If you see the moment the switch is closed current flow in this path through this, goes through this parallel paths comes through this protection resistor and back again likewise in the other half cycle also.

So, this device which your putting in here is a series device and it will limit the inrush search current. So, if you make this is variable resistance wherein if I plot or versus time this is time. So, with time we switch this resistance from high value to a low value. So, that during time closer to 0 which means during this switch on, turn on you will see that the value of the resistance is high and as time progresses the resistance of this device will decrease ok. So, this device we will be emulating it with a semiconductor device like a BJT or a MOSFET. You could either use the BJT or a MOSFET, I will demonstrate this example with you using a MOSFET for example.

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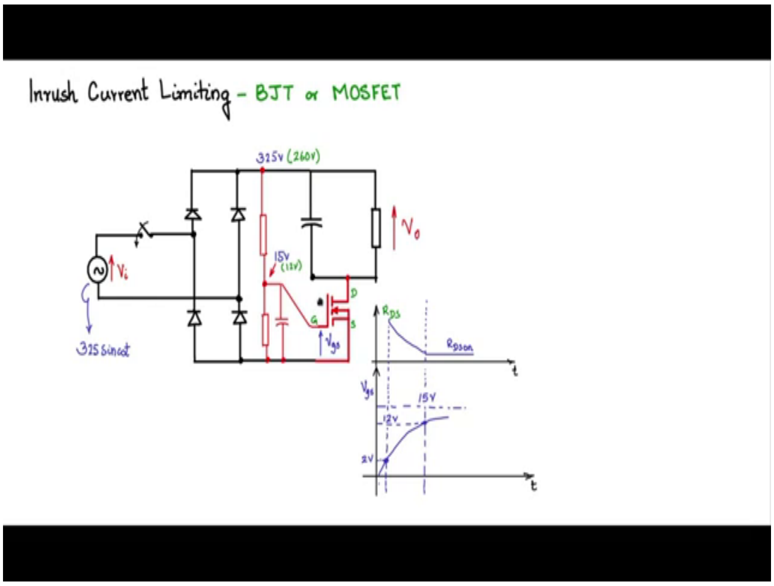


Now, let us replace this conceptual variable resistor with a MOSFET. So, let us remove this portion and let me introduce a MOSFET here, n-channel MOSFET, is an n-channel MOSFET arrow pointing towards the channel. So, let us introduce this MOSFET at this point here.

Now, here I am going to place an attenuator. So, let us first put some number, so that the understanding is clearer I am going to say that the grid Voltage is at 325 sin omega t which will give you 230 Volt RMS and here let us put an attenuator comprising of two resistors. These are low power low wattage resistors. And calculate the values of this resistors in this following manner. Let us say if it is 325 Volts here at steady state let at this point it be 15 Volts. So, that it drives the MOSFET to full on condition.

Ask the you will see that this potential is gradually rising; as it is rising if it is a 260 Volts, this will be at 12 Volts. So, the MOSFETs between 12 and 15 Volts it will be in full enhancement which means low R DS on. So, across this here let us put a capacitance and then I make a connection here and I take the gate drive for this MOSFET from here. So, take to gate drive from here.

So now, the operation is pretty simple. Now, I have the x axis is time and I would like to monitor this we get two sources, this is V gs we get two source and let us have V gs. Now, what happens to this V gs which is this point? Now, this is an attenuator and this is a capacitor this RC filter so, this is gradually going to move up to this 15 Volts. So, you will see a wave shape with time going on like that towards the 15 Volts line.

So, let us mark the 12 Volt flying, it will cross the 12 Volt at this point and at this point 2 Volt typically I am saying 2 Volt the threshold Voltage or the cut in Voltage for the MOSFET. So, beyond 2 Volt the MOSFET will be in the linear region and up to 2 Volts that is in the cut off region. So, let me mark these verticals and at the top here I am going to draw one more marking this is as drain, this is source, this is gate. What is the resistance between drain to source, R DS?

So, as this gate to source Voltage as it is increasing till 2 Volts till this point, this is in the off-state R DS will be high, be very high. And as it raises as this sun raises to 2 Volts and beyond R DS will start reducing because MOSFET goes into the linear region hear it will be in the linear region greater than 2 Volts up to 12 Volts let us say; let me extend the top.

So, you will see that the MOSFET starts going down the R DS starts going down, till at around 12 Volts is it reaches saturation and enhancement and tape flattens out and that is called R DS on. And R DS on of the MOSFET is very low. So, you will see that from the off state which is very high value of impedance here, its starts going down and in the linear region the R DS is going down and then finally, reaches a very low value of R DS.

So, the moment you switch this on V gs is gradually increasing because, this is in the off state there is no charge current flowing here, the charge control will flow this through this path and charge of this capacitors. So, as this capacitor is increasing as its starts going beyond 2 Volts this is going into the active region. So, there will be some charge flow here. The current is automatically getting limited because this is a large value of resistance. As this resistance decreases this R DS starts coming down more and more current starts to flow on this side and finally, as the V gs reaches to around 12 Volts and beyond the R DS of the MOSFET would have saturated.

So, this would be the full-on condition and which would mean that you are in the steady state from here on, ok. So, in this way this is a very nice and interesting circuit which can give you inrush current limiting simple circuit, active circuit and the MOSFETs can be for even high-power ratings and high Voltage ratings. So, instead of the MOSFETs we want to use IGBTs for higher current and Voltages that is also possible it could be an IGBT, a MOSFET or a BJT depending upon the power levels.

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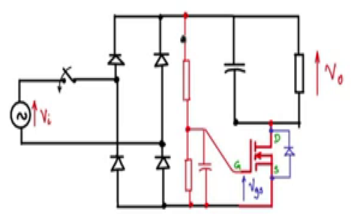

There is one problem in this circuit which is similar to the problem that we saw in the thermistor case one of time constants. Let us say this capacitor is charged up to 15 Volts, the MOSFET is in full on condition and this power goes off. The moment is power goes this capacitor discharges through the load and this capacitor will discharge through this resistance.

Now, if this time constant of this discharge if this RC time constant is much larger than this time constant then there is a situation where you can have a problem. Now, let us say after this power goes this has discharged and this has not fully discharge and the power comes back. So, during that condition you will see that this is in the charged condition and the power comes back and you can have an inrush current. So, that is a critical situation which can cause a both of any of the components.

There is further problem if you consider most commercial MOSFETs there is a body diode here. In itself the body diode is not an issue, but if you take the condition when this power goes off; switches off this power capacitor here discharges through this load. Not only does it discharge through the load it can discharge through this path parallel combination of this through this body diode and then complete this path.

So, therefore, you could see that this capacitor will always be charged up, the capacitor discharge capacitor would be discharge and when this power comes up you will see that the MOSFET is in full-on condition and inrush current. So, there is no decoupling of the discharge of this capacitance and this capacitance. In order to decouple we can put as diode here in this fashion as I will indicate.

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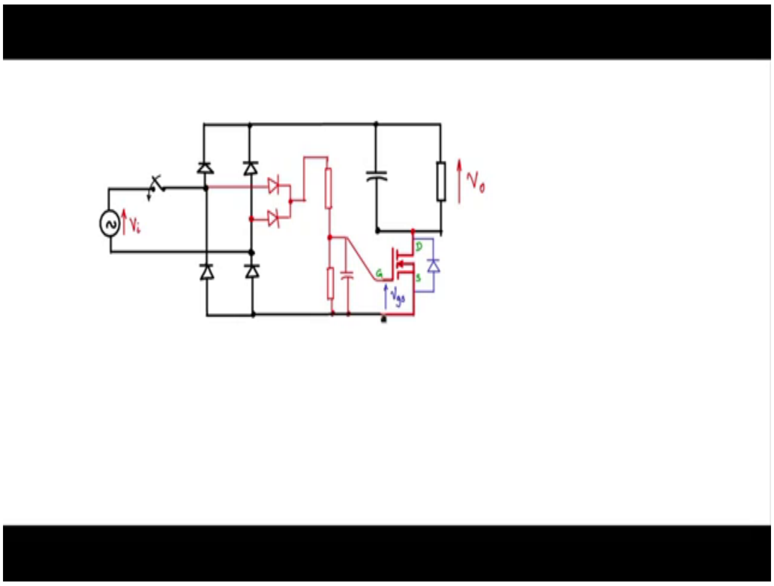

I will start modifying this by erasing here, and I will make some space by pushing it right and then make this connection, make this connection here. And now to this point instead of taking it from here, I will tap through a diode, I will put another rectifier here and from here I will tap through by putting another rectifier diode and then connect it here.

So, you see these two are low-power rectifiers currents only to deliver to this gate circuit which is the high impedance high input impedance circuit. Now, these two diodes along with these two diodes form a full bridge rectifier; this form a full bridge rectifier, supplying this capacitor load, but there is a large resistance here, so there will not be input surge current problem. These two diodes along with this are the regular power diode supplying to the power portion of the circuit.

So, when you switch on this switch, from V i the power will be supplied to this capacitor, the capacitor Voltage will increase V gs will cross the threshold value and this will go into the linear region when this will gradually start charging up. And once V gs goes to 12 Volts enhancement occurs and this will go to the full-on condition and the capacitor will be operating in the steady state. And when this goes off, when this V i goes off the capacitor will discharge through the low.