Power System Protection
Professor A K Pradhan
Department of Electrical Engineering
Indian Institute of Technology, Kharagpur
Lecture 27
Load Encroachment

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Welcome to the NPTEL course on Power System Protection. We are continuing with distance relaying. In this lecture we will see the issue with load encroachment and our discussion will be the issue with distance relay in the case of load encroachment perspective. And then what are the different mitigation techniques being used in distance relays.

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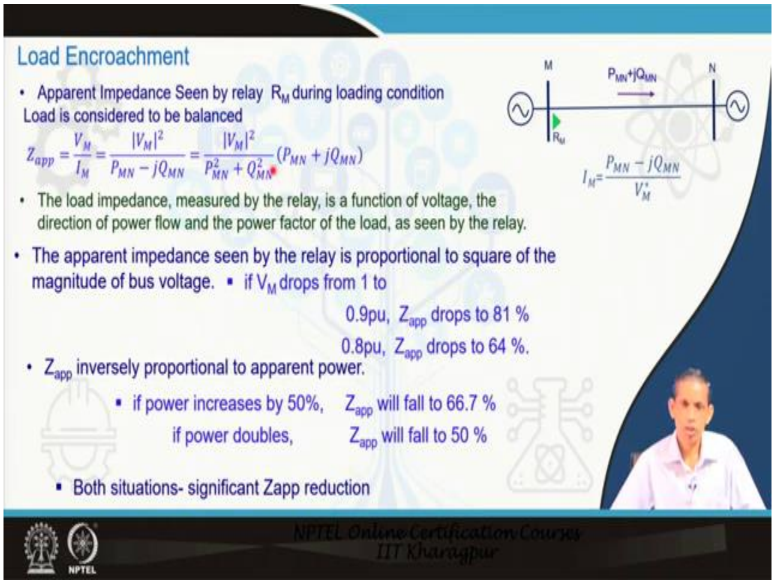

Let us come to the issue first. So we have a two bus system and there is a power flow. So the corresponding load which will be seen at bus M during that time the corresponding voltage and current as observed by the relay RM, accordingly and apparent impedance will be seen by the relay. So that apparent impedance is the issue of the corresponding discussion matter in this case. So note that we are not considering any fault here, we are only observing the load patterns through this line which the relay will observe.

For any power flow, complex power flow P +jQ, the corresponding current here that become equals to $\frac{P-jQ}{V^*}$, so that relation is known to us. Now we will see we can say that the corresponding apparent impedance which the relay you see during load flow situation, normal load flow situation. This load means in the power system high voltage system it is balance in nature.

So the relay will consider this as a balance situation and whatever discussions we have made for three phase fault also, this will be a similar situation for the relay. So therefore the relay will consider any phase voltage upon any phase current for the Zapparent calculation. And that is why we talk about here $Z_{app} = \frac{VM}{IM}$ and then substituting this corresponding Im from this relation.

We get you can say that this equals to $\frac{|V_M|^2}{P_{MN}-jQ_{MN}}$ the corresponding power, real power and reactive power flowing through the line. So this leads to another expression $\frac{|V_M|^2}{P_{MN}^2+Q_{MN}^2}(P_{MN}+jQ_{MN})$, the corresponding P and Q flowing through the line. So we see here 3 terms; V^2, $P^2 + Q^2$ in the denominator and another P and Q in the numerator.

So the load impedance, there is a loading condition so load impedance measured by the relay is a function of voltage. The load impedance this is a loading condition, load impedance seen by the relay at that situation is a function of voltage, the direction of power flow and the corresponding power factor of the load. The apparent impedance seen by the relay Zapparent at this moment is proportional to the square of the magnitude of voltage.

So that leads to situation, as the voltage drops from one power unit to lower value say 0.9 pu, from 1 power unit to 0.9 pu without change in load, assume that the square of 0.9 means 0.81, so the corresponding Zapparent will you can say that fall to 81 percent. What was the there at 1 pu, voltage.

If the voltage dips to 0.8 pu, the Zapparent you can say that as compared to 1 per unit a voltage will go to the 64 percent of that value. So these kinds of situations may happen. Here you can say at this bus if the corresponding bus may be connected to other lines and the fault may be observed in other lines then the corresponding voltage will be dropped here.

So at that time you can say that during this condition of the load, loading condition of the line, how the corresponding voltage will be seen by the RM or any other situations that may also lead to low voltage situation like a high loading situation and so. The Zapparent is inversely proportional to the apparent power as compared to these two terms.

So if the power increases by 50 percent, apparent power, then the Zapparent becomes equals to, the Z apparent falls by 66.7 percent and the power becomes double. Then we see we can say that the Zapparent will fall by 80 percent. So that you can say that the situation we can say that in terms of that so this becomes twice of the that one. So this becomes 4 times and this becomes twice.

So only two vector with be there so that leads to 50 percent, 0.5. So in both the situations when voltage dips or power flow increases, we see that the Zapparent significantly reduce.

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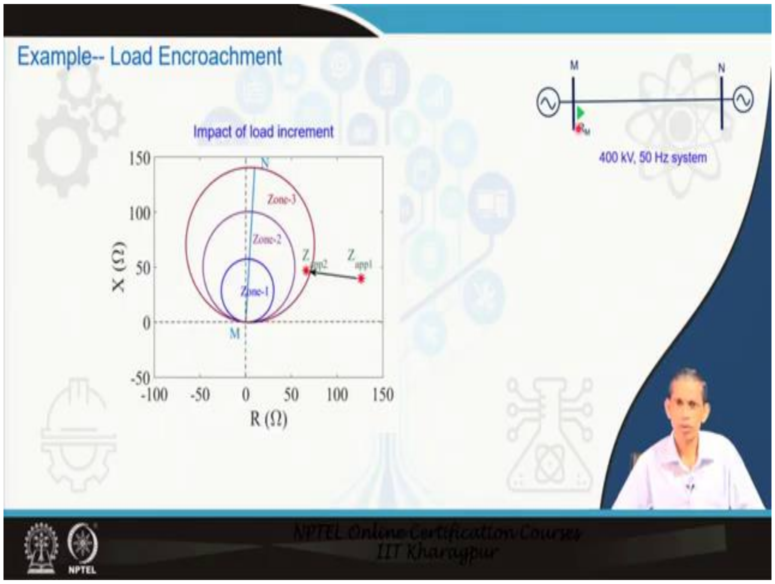

That reduction in apparent impedance is of concern now. Will it enter to the relay characteristics? Then the relay may malfunction. Take a situation of 400kV line here and the Z apparent was at a particular instant was having at this condition.

Now there is significant power flow increment here in this line. And the second case the corresponding apparent impedance seem becomes inside the zone-3 for this arrangement for the relay RM. So there is a long line issue and the corresponding power flow increases significantly. So from earlier value to this value, but this value enters inside the zone-3.

So what will happen that in this case if the corresponding fault corresponding load persist for longer period of time the time, delay time set for zone 3 then the zone 3 at this point will consider this as a fault situation and operate pick up that becomes a malfunction. So this is a security concern.

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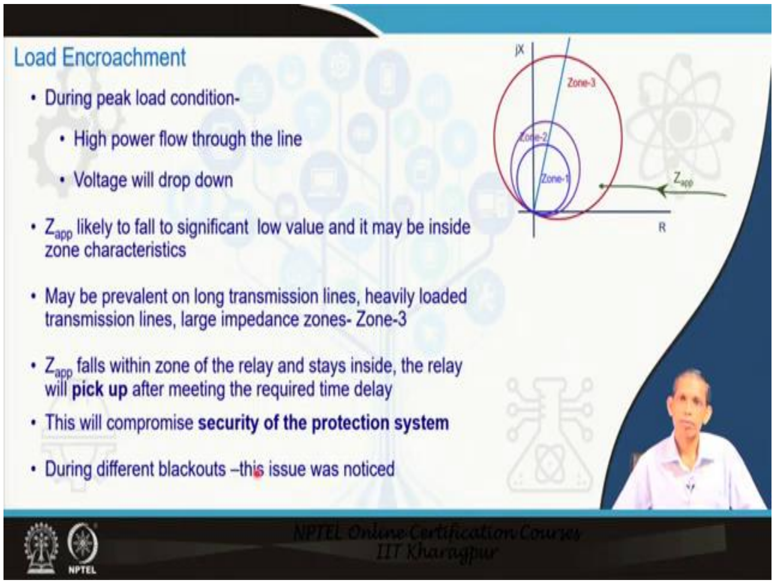

So we say that the load encroaches into the characteristics, the Zapparent seen enters into the relay characteristics during loading condition, particularly heavily loading condition then that creates unnecessary tripping security issue.

So during peak load condition, high power flows to the line, voltage may further dip, Zapparent likely to fall significantly and maybe significant low value. And it may be inside the zone characteristics so because zone 3 is the outer one larger area coverage. So that will be more vulnerable to the load encroachment issue.

This may be prevalent, this kind of situation for long transmission lines because coverage will be more for the zone 3. Heavily loaded transmission line, heavily loaded transmission line and the large impedance zones associated with zone 3 and so. So we consider if it a long line then the corresponding area coverage will be more, if it is heavily loaded transmission lines we have already observed P + jQ term will be more.

And if it is a large impedance zones if it is subsequent lines are being also longer then the zone-3 will be further you can say that larger. So the Zapparent falls inside any of the characteristics, then the relay will pick up subject to its requirements, meets the corresponding time, as you say the time delay. Now this such a pick up during loading condition, not a fault condition then it is a violation to the security of the system.

So we have already defined for the security of protection and the dependability. Security means when there is no fault, the relays will not operate. When there is no fault in the assigned section, assigned line or is the relay is taking care trips, if the relay trips that becomes a malfunction that is a security issue. Such load encroachment problem was being observed in many blackouts in the globe.

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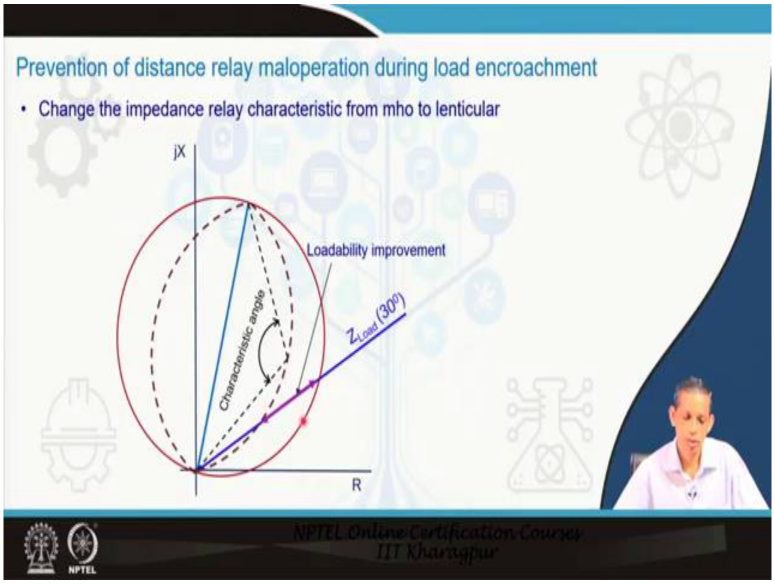

Then what is the solution in this to overcome the corresponding load encroachment in longer lines or heavily loaded condition and so. We will discuss few methods that is being those are being used. First one, Change the impedance relay characteristic from mho to lenticular. If a line is having is expected to be that load encroachment issue so what to do that the corresponding characteristics, say zone-3 characteristics.

Instead of having we can say that a circular like mho here you make you can say that lenticular like the dotted one here so that the corresponding load, the load falls you can say that close to that R axis because the power factor is pretty large in general. So if the corresponding load you can say that patterns happens to be there here in this area.

So instead of this circular if you make the corresponding lenticular characteristics for that relay characteristics where the, we expect the load encroachment problem, then we say that we have gained on the situation. So what you see that if this is the load line perspective and below this you can say that is the expected load so what we see we can say that we see here that this line segment, this portion from these lenticular at this point to this circular point here.

On this load line with an angle of 30 degree, this is the gain or improvement on loadability improvement by considering lenticular characteristics leaving circular characteristics with mho. So that what you see that for issues where we will expect such issues the transmission system for the relay characteristics. Then you can switchover the corresponding from you can say that the circular characteristics to the lenticular characteristics to expect this advantageous.

More loadability it means that even the corresponding load enters into this portion also the relay will not operate because it is having now lenticular characteristics, not with mho characteristics.

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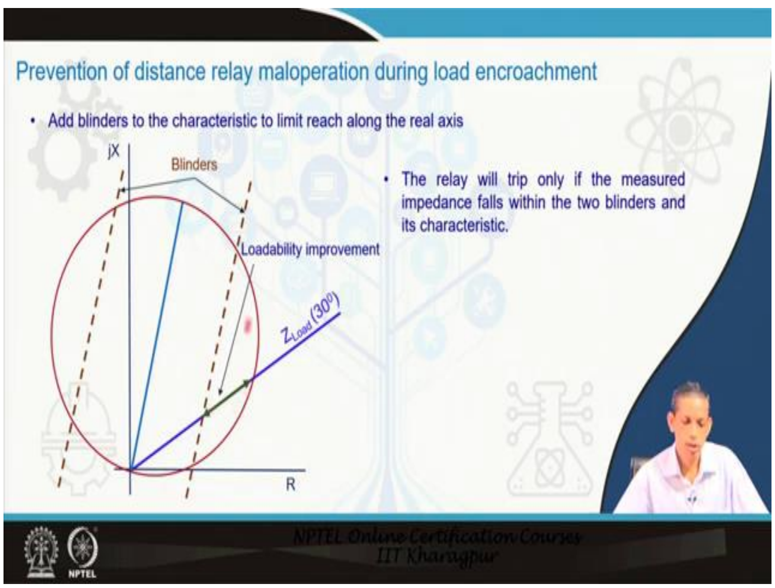

Another option, add blinders to the characteristics to limit reach along the real axis. So as I said this is the portion for the load so what will be that? Suppose this is a mho relay characteristic also, you put two blinders the dotted lines blinders. These are parallel lines with the load line. The transmission line impedance line, line impedance line, this is impedance line and it parallel with that.

So what do you do that even the load comes this portion the relay will not trip because it is beyond the blinder, it is beyond the blinder even though it is inside the mho characteristics. So the relay will trip when it inside the characteristics and also for this you can say that right hand lambda it is left of that.

Then only you can say that it will be, so it will be corresponding point falls within the blinder and also in the characteristics then only you can say the relay will trip. That will ensure that this is a fault. So therefore in this case because the relay will not trip in this portion also, so we will have a, because this is the area of load we can say that the load so we have a gain of we can say this portion and that is what the loadability improvement by using the blinder concept.

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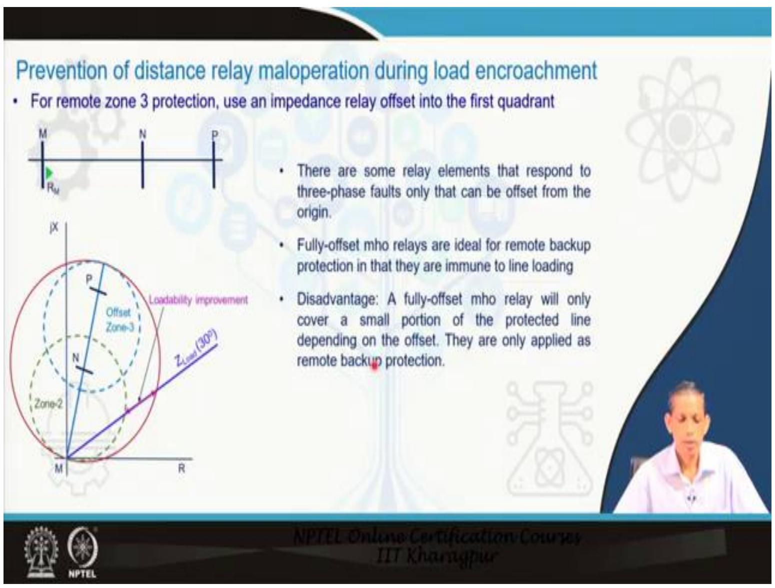

The third one will see that for remote zone-3 protection, this is what the zone-3 protection use an impedance relay offset into the first quadrant so what you do that the problem we can say that we see that the load encroachment issue if you see that you can say that the load you can say that may come inside this one. So instead of that, to have this you can say that the corresponding line backup protection for this line zone-3 will be here.

This zone-3 will you can say that make an offset one and like this not like this one. So therefore the relay we can say that here see for any fault in NP which should be taken care by this relay so that characteristics becomes this, the offset one, not this one. So thereby what you say that the corresponding relay you can say that, the loadability improvement will be this portion in this case.

So that is about the backup protection from relay RM for the NM portion. So the disadvantage of this is a fully offset mho relay will only cover a small portion of the protected line depending upon the offset, of course the purpose is for the backup.

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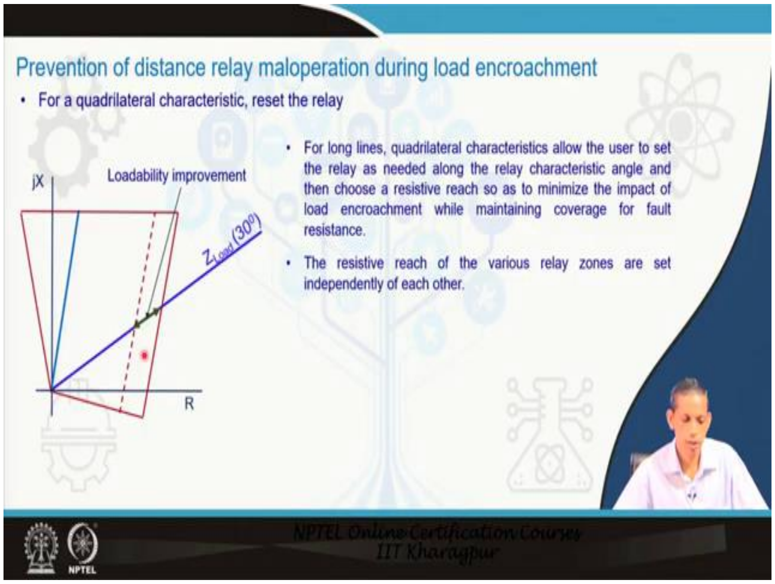

The other one is a quadrilateral characteristic setting. So what we see here that in these kind of situations, if we expect to the cover the RF for you can say that let us say zone-3 relay having this. But if the corresponding relay characteristic is expected to be load encroachment issue, so we reduce the coverage, you reduce the coverage and thereby we can say that, we can exploit the advantage of this portion as the improvement portion.

So even you can say that a load we can say that falls in this area also. It will not go for a trip decision. So this we do not require everywhere we require when there is load encroachment issue.

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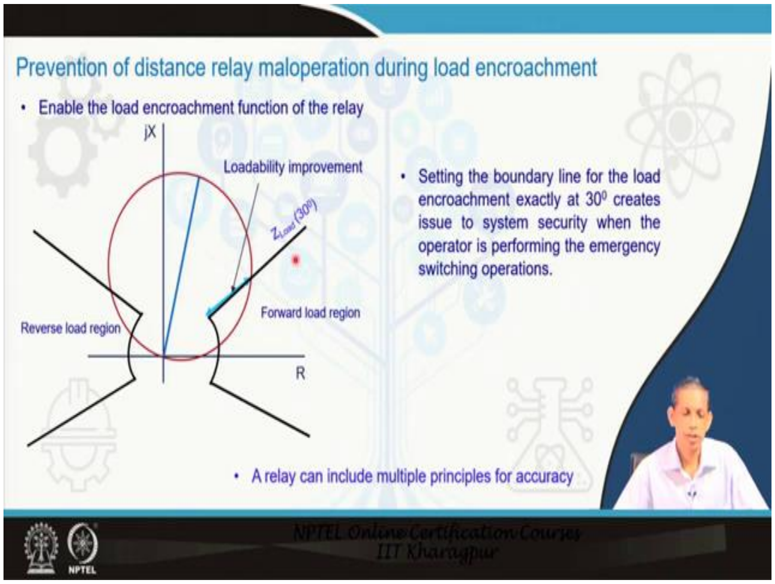

The other one option is that the enabling the load enforcement function. So we have a special characteristic for this load perspective. So typically you can set these two lines 30 degree, 30 degree but and then you can say that in both the sides forward region and the reverse region, this we consider the load. So therefore we can say that in the mho characteristics also, this portion we can say that will be not allowed to we can say that trip.

So therefore you have an advantage over gain in the improvement on the loadability perspective. So any point we can say inside this portion is a considered as a load and the relay will not trip, relay trip when you consider it is beyond this and inside the characteristics. However the 30 degree is not you can say that fixed option. Depending upon we can say that it is being observed that different emergency situation this corresponding these lines setting 30 degree may not be proper.

So in that kind of situation and all these things, this would be a different angle perspective. Now we see there are different options for mitigating the maloperation issue associated with load encroachment. We can have a better option also by combining 2-3 we can say such options for better performing in this regard to have a better accuracy. So what we see we can say that is that load encroachment creates problem and it needs mitigation strategy and there are different options available.

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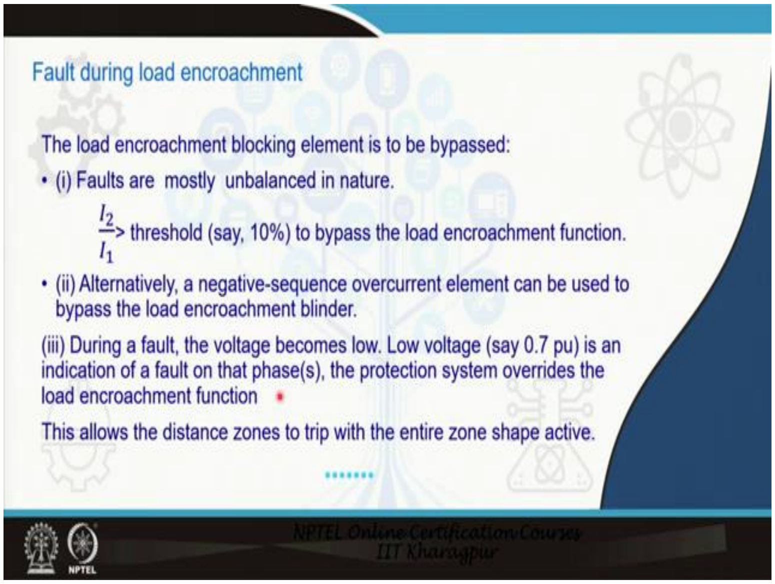

Now take another issue. If a fault happens to be there during a load encroachment period, try to understand the apparent impedance seen by the relay is in the load encroachment area and at that time the relay is blocked because it should not trip. And if fault happens to be there in that zone, because this is a fault so the relay must trip, the relay is to take care.

So therefore the corresponding blocking phenomena because of the load encroachment issue prior to the fault must be withdrawn. Then how to have this in the relay characteristics? The load encroachment blocking element is to be bypassed one option, easy option. Most of the faults are unbalanced, so what we do that we there will lot of negative sequence current, so negative sequence current up positive sequence current greater than the threshold, small value let us say 10 percent or so, if these we can say becomes significant, as to this threshold then we ensure that there is a fault in the system. So we can bypass the load encroachment function.

There are other option also, negatives sequence overcurrent element can be used to bypass the load encroachment also, simpler from the negative sequence overcurrent also we can do. Third option during a fault the relay voltage will go down, will we low. There will be voltage sag issue, voltage drip issue. So if the low voltage say less than 0.7 pu is observed in the any of the phases, then the it is considered that there is a fault and the load encroachment function can be bypassed at that time.

So thereby this approach, this allow the distance you can say that relays zones to trip and using the full zone area associated with that zone. So what we see from all these that load encroachment is a problem for heavily loaded line or long line and also associated we can say that the zone-3 of the relay.

To overcome that, there are different options available, including the load encroachment function. However fault may occur in during the load encroachment one to bypass the load encroachment function or so we require special other principles, features and that will lead to the corresponding solution for that perspective. Thank you.

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