Cathodic Protection Engineering
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Lecture – 07
Cathodic protection engineering: Anode ground bed for cathodic protection

Hello, today we will talk about the Anode ground bed for cathodic protection.

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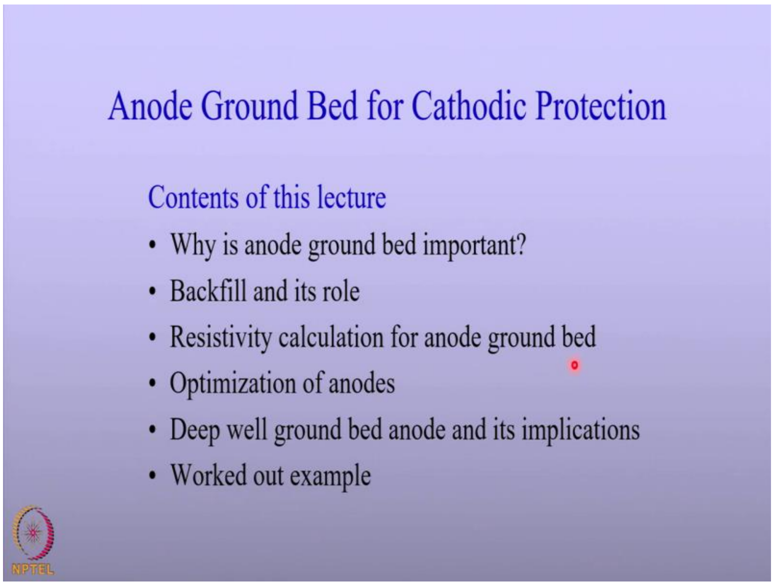

The content of this lecture is listed here; we will start with highlighting why one should worry about anode ground bed. The role of backfill and in the location of we shall then talk about backfill and its role. The resistivity of the anode to ground bed is very important we shall look at the governing equations. So, that we can look at the governing equations to calculate resistance of the anode that offers for the current flow.

And, then we will move on to optimization of the anodes. And, there are cases where we need to look at the deep well ground bed anode and we will see how important to have the deep bed. We shall also see, how important it is to have deep well ground bed anode in some cases. If, the time permits we look out an example, how to calculate the resistance of the anode ground bed from there how we will see the rectifier capacity can be determined.

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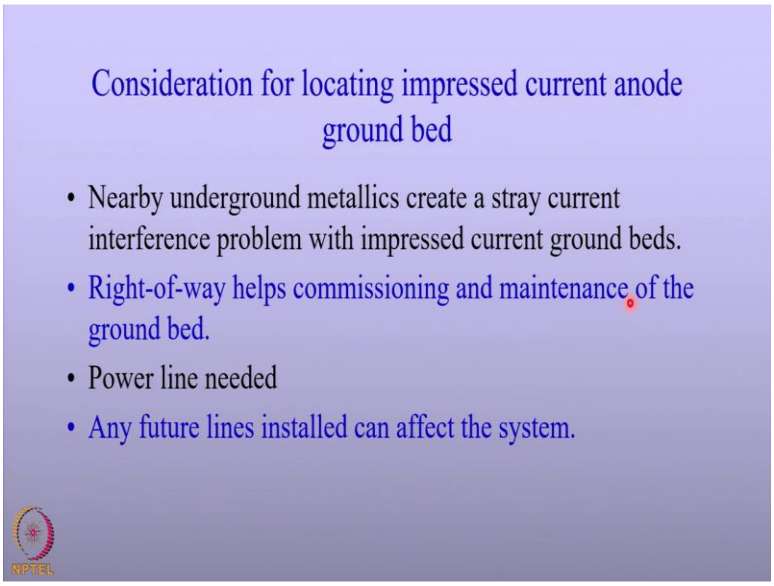

This ground bed is location is very important as far as the impressed current anodes are concerned. This is less critical when you talk about the sacrificial anodes. This is basically because the impressed current anodes they carry huge amount of current and so, the resistance of the anode to the soil becomes very significant. And, so, the location of the anodes are very very important. It is and when it when you talk about, the location of the anodes would depend upon the following four aspects.

The location of the anode should be such that, it should not create any stray current corrosion interference with the nearby metallic structures. And, it is important that the anodes are regularly maintained. So, the right of way to reach these anodes are very important. And, so, to secure right of away is an essential part of the locating the anode ground bed. Because, the sacrificial anode systems does not need any current, we do not worry about power lines.

As opposed to that the impressed current anode systems they require power lines and so there is a very important part of locating the anode ground bed. It is also one should look at what could happen, if there are any future lines installed in the nearby systems. Because, there can be electrical interferences, which can cause stray current corrosion problems.

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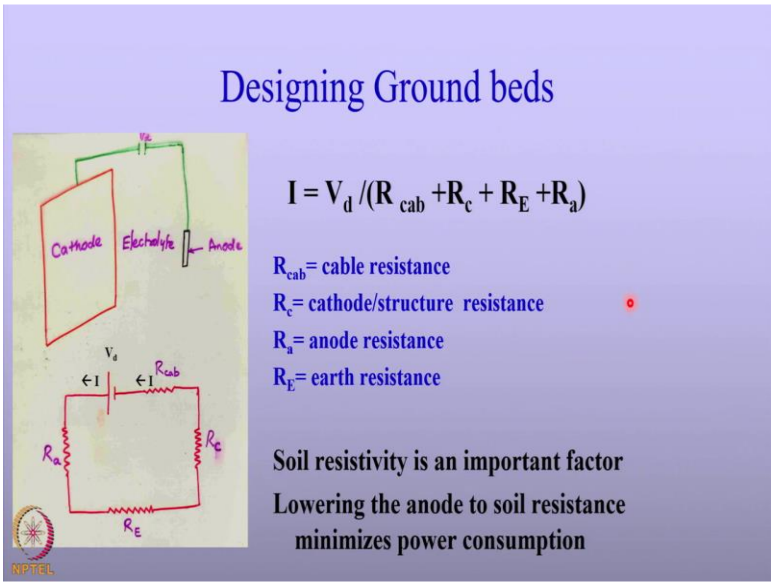

The designing ground bed, before we go into details I like to draw your attention to this diagram shown on the left side of the slide. What is shown here is the cathode representing the pipeline, the anode that you see here. So, what is very important is the size of the anode in relation to the cathode. The size of the anode is very small in fact they are like a point.

And, so, the current that is passing through the anode and cathode are similar. However, the current density that leaves the anode is quite significant. As a consequence, there will be huge potential drop that is taking place from the anode and then to the soil. So, this is an important factor in considering the anodes.

In electrical equivalent of this cathodic protection system is given below, that is given here as the resistance offered by the cable that you see here. The resistance offered by the pipe to the soil, the resistance offered by the anode to the soil and then the resistance offered by the earth or the soil.

We ignored the resistance offered by the soil because of the large area through which the current is flowing in the soil. So, that becomes very insignificant we normally do not consider this. The relation between the current, the voltage drop and the resistance offered with these are given by simple Ohms law.

And, the resistance contributed by the cable, the cathode, the soil and the anode here ok. They all contribute to the voltage drop that happens in the circuit for a given current that is required for cathodic protection. As you notice that the soil resistivity is an important factor, because that influences the resistance of the anode in the ground bed and as well as the pipe to the soil resistance. So, lowering the anode resistance, lowering the anode to soil resistance minimizes the power consumption.

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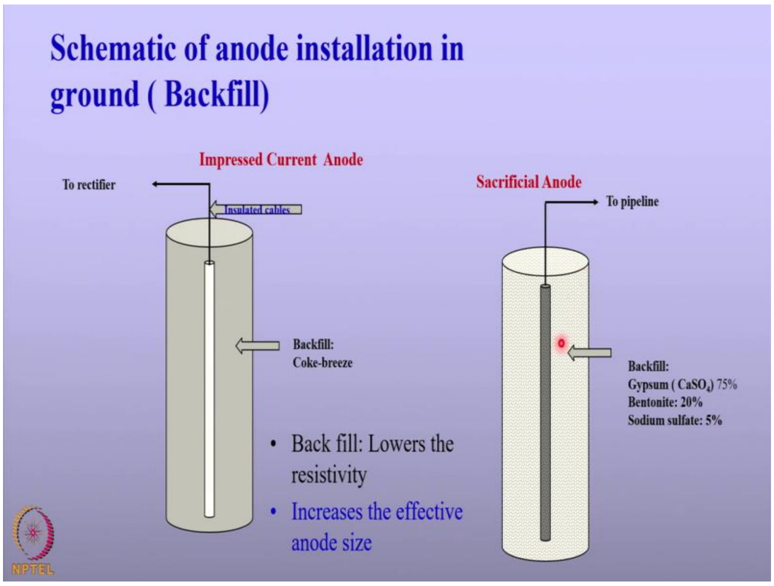

Because, the current has to move through the soil from the anode the surrounding area of the anode should be highly conducting. The soil many times have very high resistance, in order to lower the resistance, backfill is normally employed.

This schematic shows the impressed current anodes and the sacrificial anode surrounded with backfill. Between these two cases the nature of backfill is different. In the case of sacrificial anode the backfill consists of gypsum bentonite and sodium sulfate. And whereas, in the case of the impressed current systems, the backfill is mainly made up of coke breeze.

The coke breeze is not used in the case of sacrificial anode, because it can cause the galvanic corrosion between the sacrificial anode and the coke breeze. The one of the difference between the sacrificial anode and the impressed current anode system is that, in the case of impressed current anode system. The cables required to be insulated whereas, in the case of sacrificial anode, it does not matter much, because these cables vertical cables are also cathodical protected by these sacrificial anodes.

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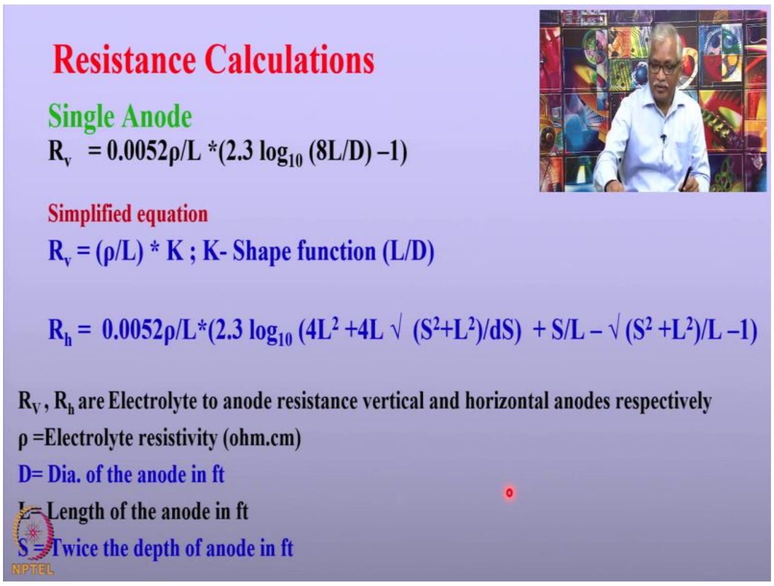

Let us look at the resistance calculations. In coming to resistance calculations you notice that there are two types of anodes in terms of configuration; one is vertical anode with respect to the pipeline and other is the horizontal anode, which is in relation to the pipeline, because they are parallel to the pipeline.

So, the resistance equations it depends upon the kind of configuration that one uses. The equation that is given here corresponds to the resistance offered by a single anode in the vertical configuration. What is very important here is that the resistance resistivity of the soil plays a very important role. The anode dimension also is important you can see here the length of the anode and the diameter of the anode here.

This equation is also simplified in order to make the calculations simple, by using a parameter called as shape function. The shape function is available as say table for different L/D ratios by substituting the K function here the K, it is easy to obtain the resistance offered by a single anode in the vertical configuration.

As opposed to the resistance for a single vertical anode, the resistance offered by the horizontal anode, as a very complex equation you can see here. And, nevertheless it is possible for us to calculate the R_h value by substituting these parameters.

Now, what is the additional parameter that is that comes over here in the horizontal anode is the depth of the anode in feet; what depth these horizontal anodes are buried in the soil ok. The yes corresponds to the twice the depth of the anode in terms of feet. What is to be noted here is the units here are you know is not a normal thing, you see you can see here as you use a feet here instead of SI units. Now, this is about a single anode seldom one uses single anode in cathodic protection, we use multiple anodes.

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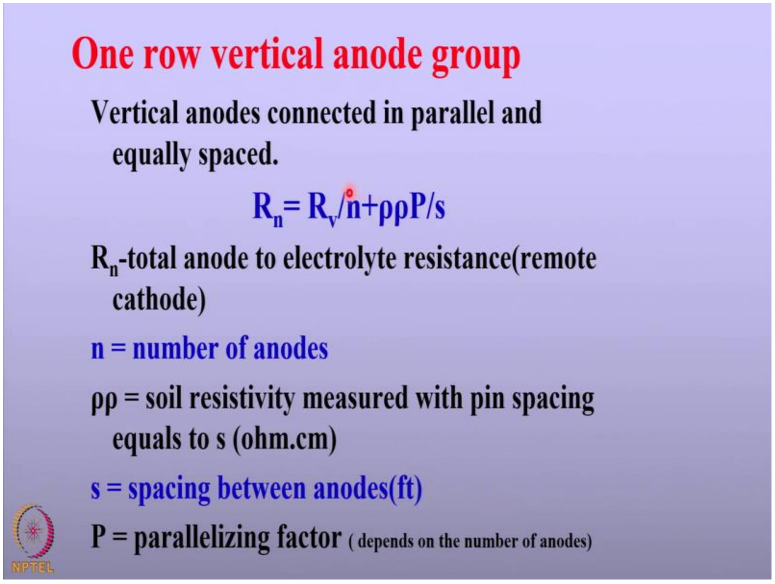

So, the resistance offered by multiple anodes are given by this equation, the number of anodes that are used for cathodic protection right. If, the number of anodes are increased you see; obviously, the resistance offered by the anode ground bed is decreasing. So, you can lower the resistance offered by the ground bed by increasing the number of anodes here.

So, this equation is used to determine the resistance offered by large number of anodes and you will see later how many number of anodes are required can be calculated for a given system. There is one factor which I need to mention that is called as the paralleling factor here, there is finding in this equation and that is can be obtained again from the tables, that depends upon the number of anodes that are used.

It is a important notice that the resistance offered the measured here ok. Corresponds to the pin spaced at a distance equally s and the s corresponds to the spacing between the anodes that is typically installed in the cathodic protection system.

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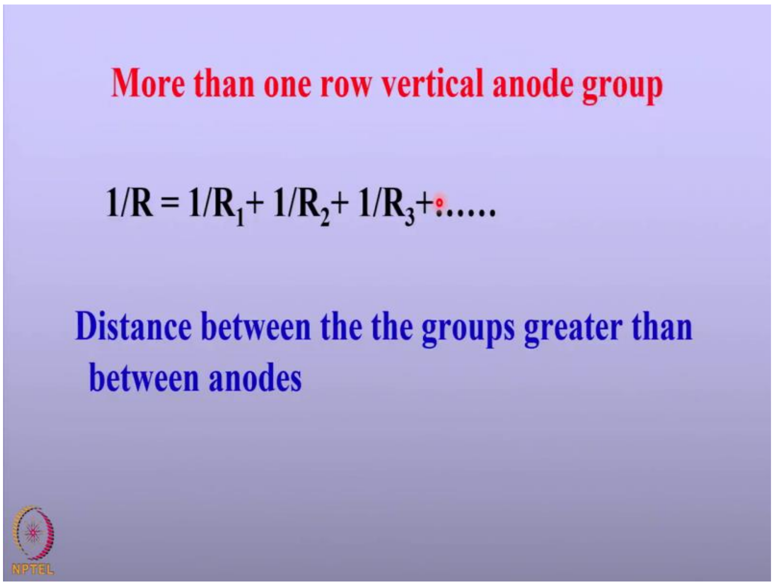

One can also reduce the resistance offered by the ground bed by adding several vertical anodes rows. So, in this case we use a simple in equation like, this 1/R we all know that $1/R = 1/R_1 + 1/R_2 + 1/R_3$. Each R_1, R_2, R_3 represents the resistance offered by one group of anodes.

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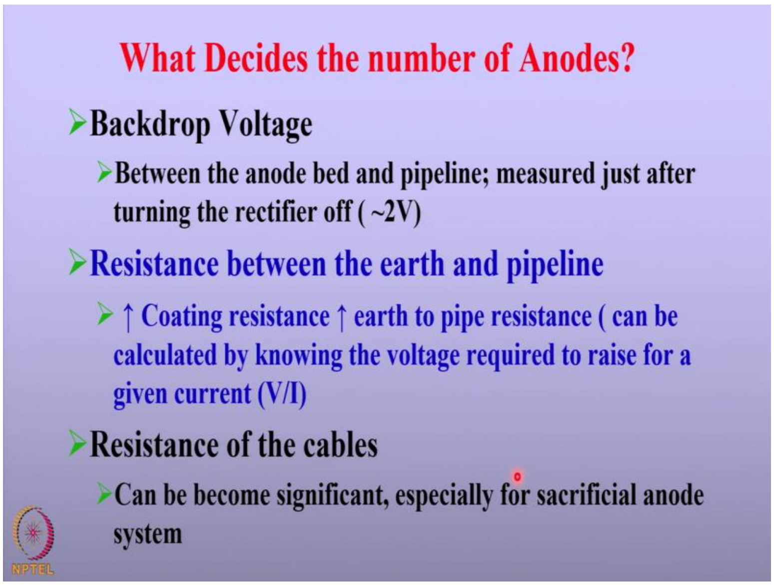

Now, what decides the number of anodes? This is an important question that one has to address in deciding the number of anodes; we will see later that when you increase the number of anodes the cause also increases. There are other issues like maintenance of the anodes.

The three factors they decide the number of anodes. The first is the backdrop voltage. The backdrop voltage is nothing but the voltage between the anode and the pipeline when you turn off the current. Just after turning of the current you measure the voltage between the anode and the pipeline, that voltage is equal to the backdrop voltage.

That is actually the resistance that is because of the fact that, when you apply a cathodic protection, there is a resistance for the current flow between the pipeline and the anode. So, this is the value that has to be taken care of in deciding even the rectifier.

The other factor that decides the number of anodes is the resistance between the earth and the pipeline. Current passes from the earth to the pipeline and against a resistance offered by the pipeline to the earth. The resistance offered by the pipeline to the earth constitutes two factors; one the coating resistance, the coating that are applied onto pipeline. In fact, if you apply a very good coatings, the resistance offered by the pipeline to the earth becomes very high.

It also depends upon the earth the resistance of the soil ok. So, they all add to the overall resistance of the pipeline to the soil. And the earth to pipe resistance in fact can be calculated by applying a known current, required for cathodic protection measure, the voltage and ratio between the voltage and current gives the resistance offered by the pipeline.

So, this is actually a measured value in the field. In addition to these resistances we have seen a electrical equivalent circuit, the cables also can offer resistance. The resistance offered by the cables they become very significant, when sacrificial anodes are used.

We know that the sacrificial anodes have definite potential with respect to the soil. And, therefore, even a small increase in cable resistance can significantly lower the ability of the current to flow into the circuit.

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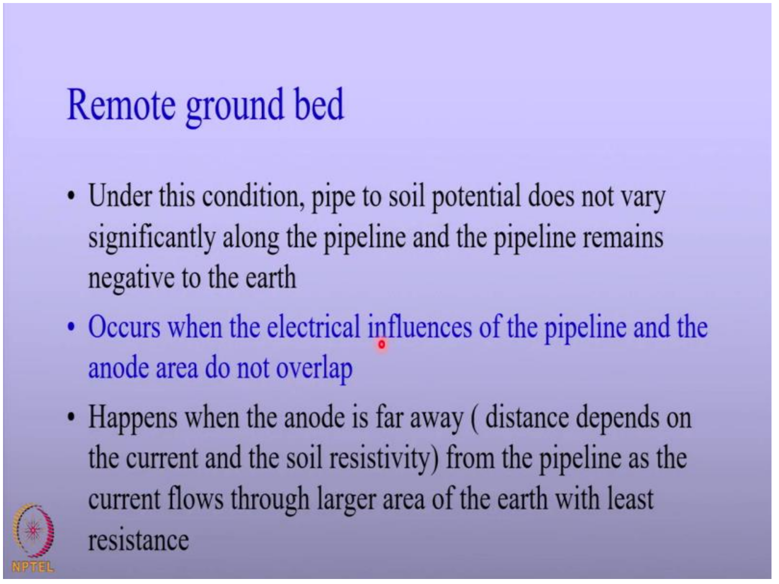

Let us look at the other important factor when you talk about anode ground bed. The concept of remote ground bed is very important in the cathodic protection engineering of structures. Why is that we worry about remote ground bed? Because in a typical pipeline which is cathodical protected you like to ensure that the pipe to soil potential along the distance, they remains almost the same.

One does not want to see a situation, where the pipe has got high soil to potential; high pipe to soil potential at a location close to the anode. Normally, if you do not maintain a remote ground bed, the piped soil potential close to the anode bed becomes significantly very high. And, thereby causing a problem such as hydrogen embrittlement and as well as cathode disbandment of the coatings.

So, the remote ground bed ensures that for a long span of pipeline length, the potential remains almost constant within the level of cathodic protection required. Now, the remote ground bed is possible to establish, when the electrical influences of the pipeline and the anode area do not overlap ok. So, there is a field across the pipeline and there is a field across the anode and the electrical influences of these two how to separate it that can happen only when the anode is kept far away from the pipeline.

Now, how far it has to be kept that depends upon the current how much current is required to protect cathodically and as well as the resistance offered by the soil. In high resistance soil the anode ground bed generally moves far away from the pipeline.

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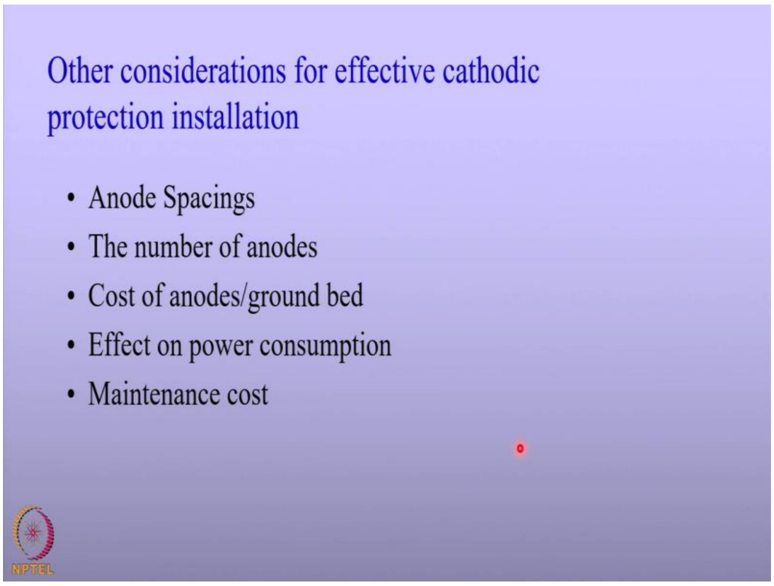

The other considerations for effective cathodic protection installation involves the anode spacing’s, the number of anodes that are going to be employed, the cost of the anodes, ground bed, the effect of power consumption and the maintenance cost. So, I say illustrate these I illustrate these factors in the couple of slides.

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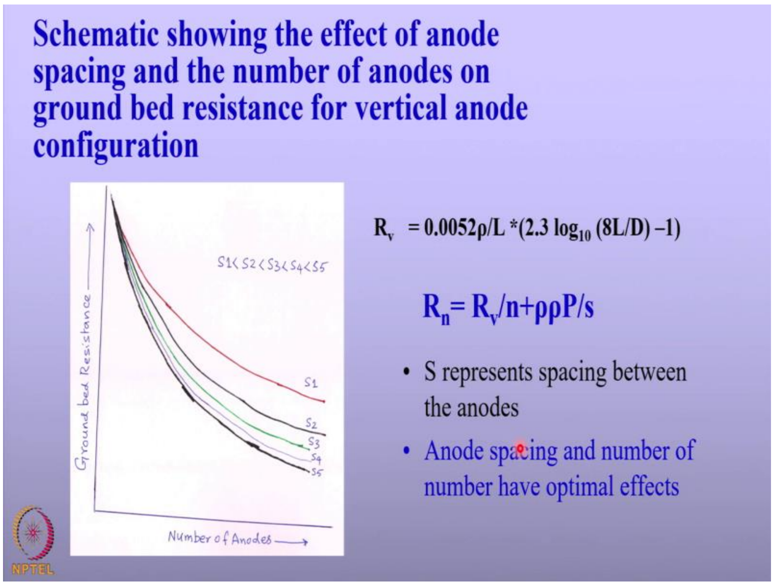

Let us look at how the number of anodes can affect the ground bed resistance. In addition to the number of anodes, the spacing between the anodes also can affect the ground bed resistance. This is possible because the equation here, this is this corresponds to the resistance offered by a single anode right.

If, you have a multiple anode the R_n will depend upon the number of anodes here and the spacing between the anodes. So, one can able to calculate, the variation of the ground bed resistance with respect to two parameters; one the number of anodes and the spacing between the anodes.

So, what is shown here schematically on left side is the relation between the ground bed resistance and the number of anodes for varying spacing between these anodes. As you notice, in this plot irrespective of the spacing between the anodes. The number of anodes are increased the ground bed resistance steeply decreases almost asymptotically, beyond then the certain number of anodes of course, they decrease in ground bed resistance becomes less significant.

Similarly, if the spacing between the anodes are increased as you notice from S_1, which represents the lowest spacing to the highest spacing see here, then the resistance offered by the ground bed decreases. So, why does the spacing lower the ground bed resistance for the cathodic protection of structures?

But however, you also notice that, if the distance between the anodes if they are increased I think the effect of this distance becomes smaller and smaller as you increase distance beyond certain levels. So, it is also important that we optimize the spacing between the anodes.

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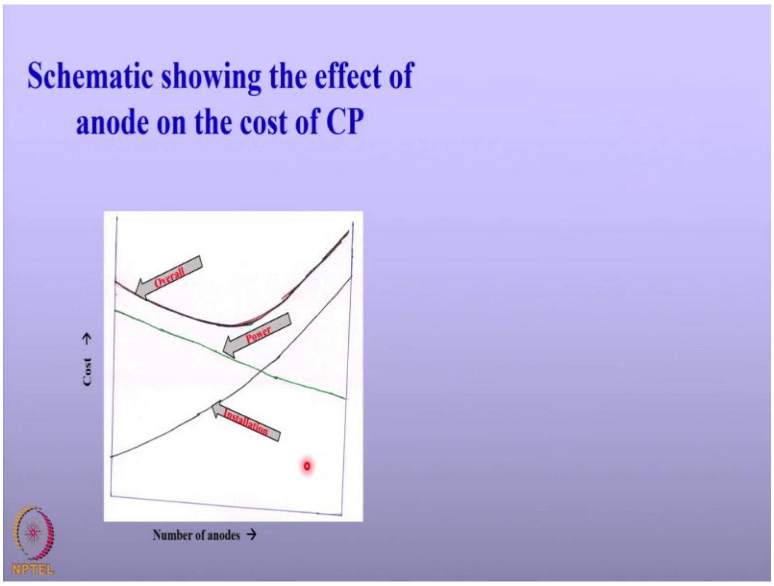

So, we have seen that, if you increase the number of anodes the ground bed resistance decreases and when the ground bed resistance decreases; obviously, the capacity of the rectifier in terms of voltage, or the power consumption decreases actually ok.

You see in this diagram ok. The cost per power right, the cost per power decreases if the number of anodes are increased, it decreases almost linearly with respect to the number of anodes. But, you also notice that, if the number of anodes are increase the cost for the installation of the anodes increases.

It increases not linearly in fact; you know somewhat exponentially it increases. And, so, the overall cost for cathodic protection, installing the cathodic protection lies somewhere in between here. So, that is given by this upper curve, it shows that the cost of installation of the cathodic protection system, running the cathodic protection system, it decreases and then starts increasing if the number of anodes are increased.

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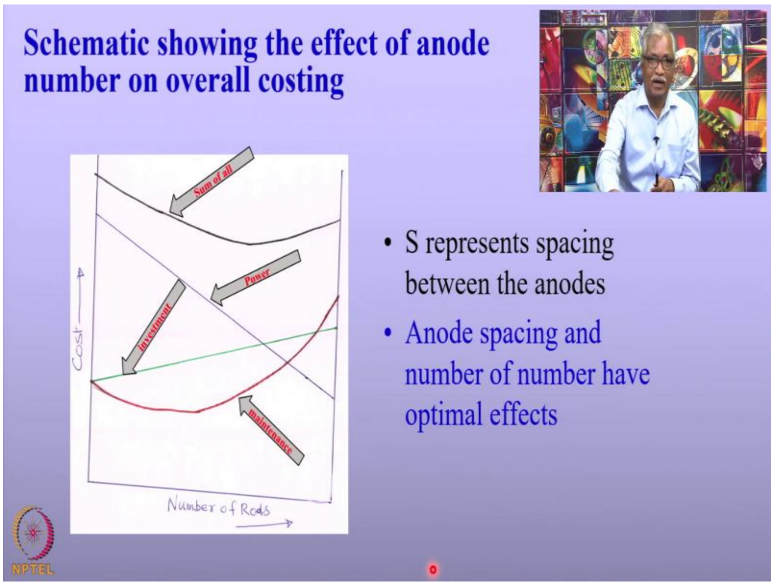

There are other factors that should be taking care of when we decide the cost of the cathodic protection system. There is one more factor that we need to take into account is shown in this in this graph, that is the maintenance.

As you notice that, if you increase the number of anodes, then the maintenance of these anodes they become very important. And, you as you notice that, initially the cost of maintenance is almost you know remain the same ok. And, but then the cost increases as a number of anodes are increased actually.

So, to sum up all of them you see that the cost of the cathodic protection goes through a minima and the number of anodes should be chosen as per this calculations.

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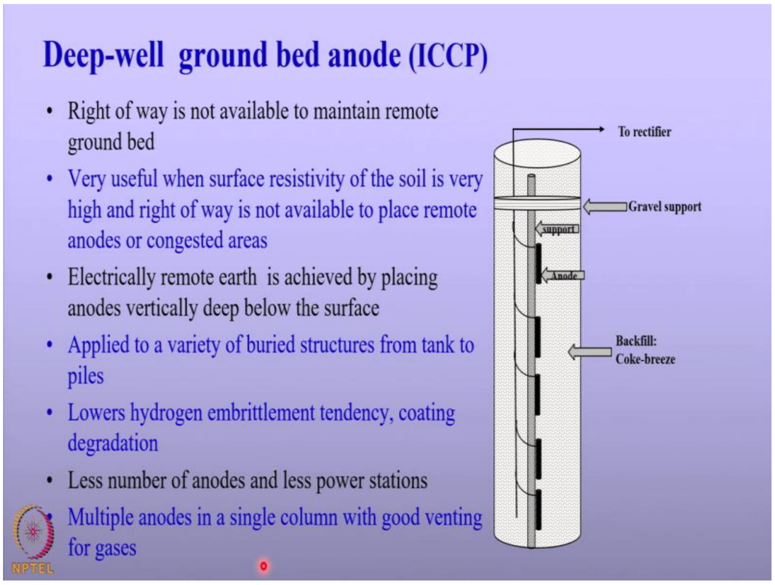

We have discussed that remote anodes are important for cathodic protection of the structures. However, there are situations where that is not possible. One is that it is not possible to obtain the right of way; that means; it is you do not have a land. So, that you can install the anode at a far away distance, that is one of the possibility.

The other possibility is that the resistance a resistivity of the soil is quite large. So, that makes remote anode ground bed more difficult. There are also cases where, there are electrically interferences taking place you know. So, there is also a problem. So, there are three factors; the right of way is not available for you, the soil resistivity is so, high and in fact, sometimes they may be congested areas or the rock areas for example, it is not possible to keep an anode remote if they happens to be rock area.

So, in such a case deep well ground bed anode is a right choice. In order to establish remote ground bed. And, what is shown in this diagram is a schematic of a deep well ground bed anode system. In over here the anodes are kept deep in a well; in fact, it can be placed very close to the level where the water is available right.

And, because the resistivity over there is very small establishing remote ground bed becomes quite easier. Over the deep well ground bed anode, generally we do not use a single anode, multiple anodes are used one of the advantages of using multiple anodes are that, if even one anode fails, the other anode start functioning. By having a deep well ground bed anode as we establish remote ground bed, it lowers the tendency of hydrogen embrittlement of metal very close to the anode and it also avoids coating disintegration.

The less number of anodes are required, the less power stations you do not have to have multiple stations actually. So, that is an advantage of that. And, in establishing the ground bed deep well ground bed anode, one has to also ensure that the gases evolved from this ground bed should be properly vented.

Because the voltage applied over here is relatively higher there is a chance that chlorine evolution other gas evolution possible. So, there should be proper bent in order that the anodes are not getting damaged.

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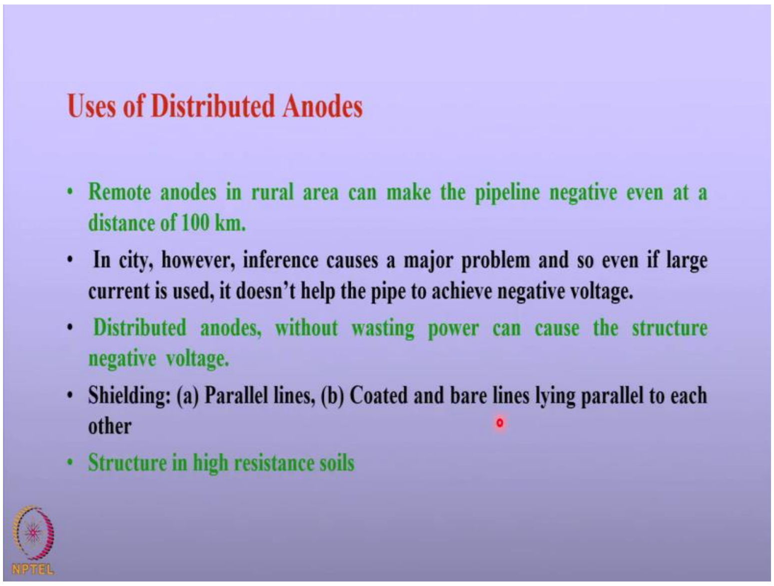

Where we do not, where we have the problem of establishing remote anodes? Ok. And, where is also not possible to have deep well ground bed anodes? You look at the possibility of distributed anodes.

Now, as you notice that in a area where, that not much of a congestion the pipeline is placed in a place where there are no nearby metallic structures. It is possible to have remote anodes that will distribute current over a long distance as much as 100 kilometers. But; however, in urban areas, where you will see multiple pipelines is very likelihood of causing interferences.

So, establishing a single anode station is not very easy, in which case we go for distributed anodes. And, the anodes are so, well distributed that the current that passed is very small when the current passed is very small you will have less over potentials on the pipelines.

So, wherever you have parallel pipelines and coated and bare pipelines lying parallel to each other distributed anodes are used ok. So, this is another way of overcoming the interference problems, where you see large number of metallic structures.

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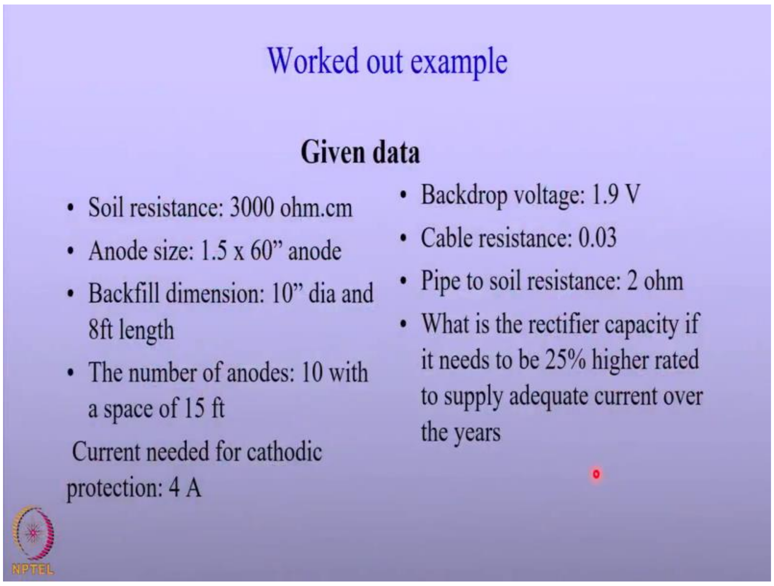

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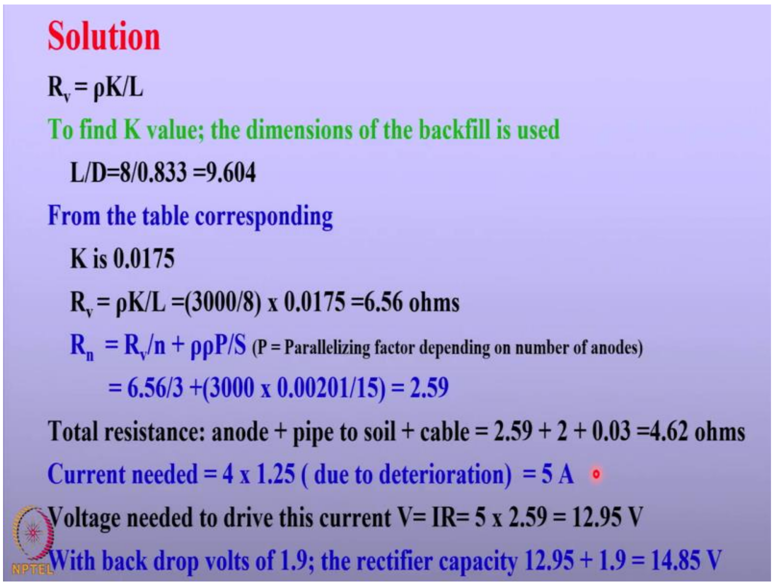

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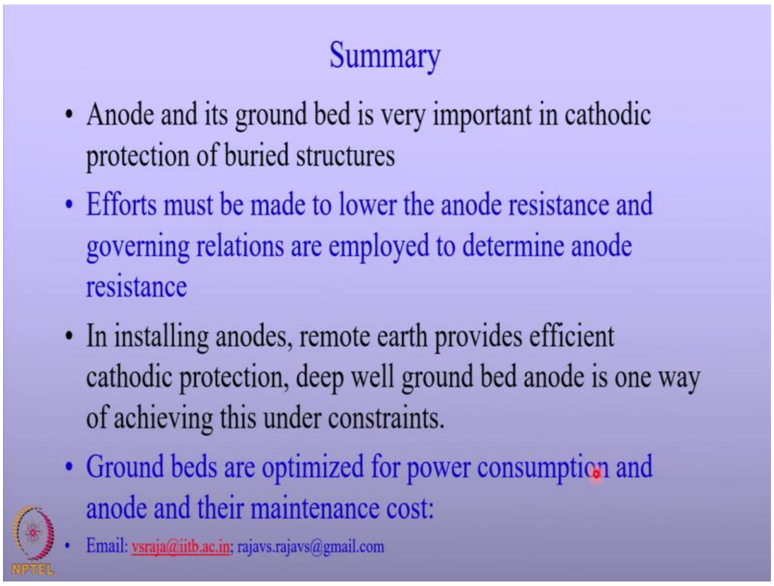

As, I skip the problems we will see later, I would like to summarize today’s lecture. Anode and it is ground bed is very important in cathodic protection of buried structures. It is very important that it reduce the anode to soil resistance that is done by having a backfill, in efficient backfill; it is also done by increasing the number of anodes that required and where.

The one of the important; one of the important point to be considered in establishing the ground bed is you must have remote earth. So, that over a long distance the pipeline is protected very uniformly. In the ground beds are optimized for power consumption and anodes under maintenance cost.

Thank you.