Advances in UHV Transmission and Distribution
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Lecture – 28
Importance of Grounding, reducing Earthing resistance

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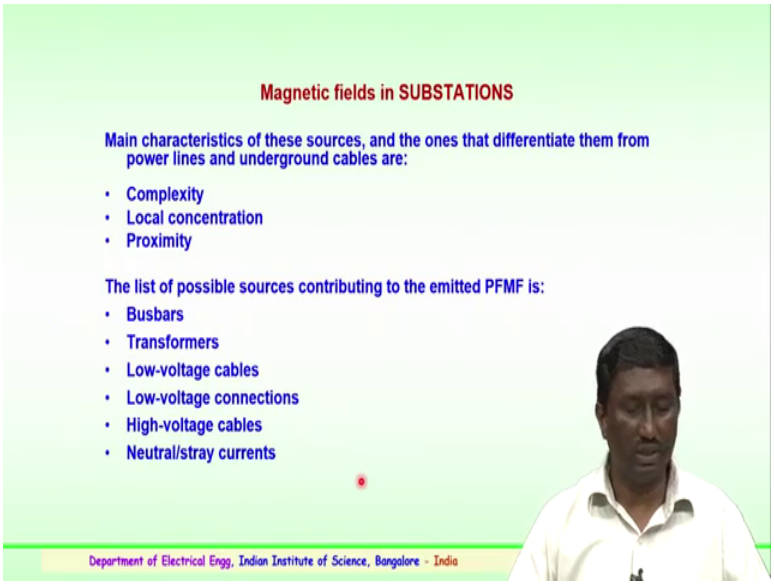

So, coming to the magnetic fields which are being generated in the typical substation. Substations again could be of extra high voltage any high voltage substation, depending upon the voltage level depending upon the power which is being distributed. So, this forms very important. The main characteristics of the sources and the ones that differentiate from the power lines and underground cables are basically in substation is the complexity of the arrangement in a substation. The local concentration and also the proximity effect several of these things come into the causing the effect of magnetic fields in the substations.

The list of possible contributing magnetic fields which are emitted because of the power frequency magnetic field could be the busbars, that is high voltage conductors, the transformers the important component in the substation. The third being the low voltage cables which are being connected in the substation then low voltage connections could be of control cabling or for the metering panels. So, these also would like to contribute,

then high voltage cables the neutral and stray currents which are normally witnessed in the substation.

So, these all the these things could be possible sources which contribute to the power frequency magnetic fields in the substation.

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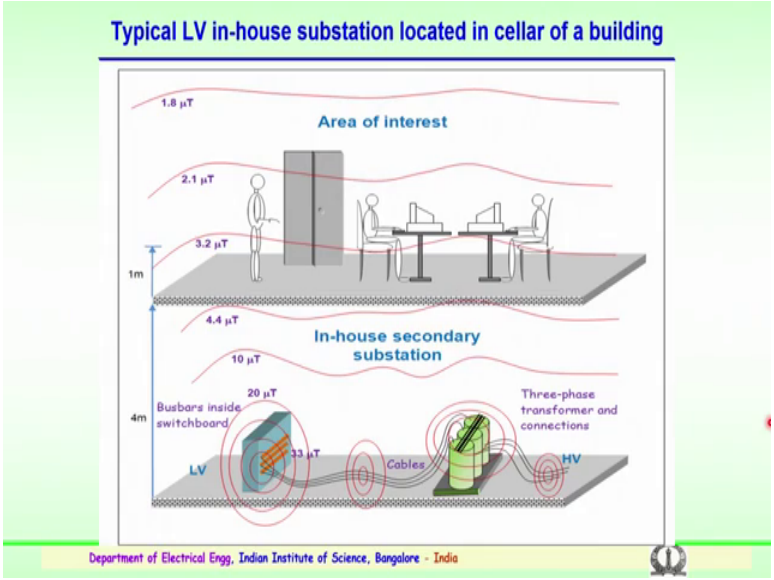

So, typically low voltage in house substations, which could be located in a cellar of a building could also be emitting the magnetic fields because of the substations being in the ground underground the ground floor, and the office or a scada center or a control room could be of the first floor.

So, here again the electric field may not be of consequence magnetic field are of concern. So, proper management and proper planning is essential and the measurements have to be carried out for the emission of magnetic field by the equipment which are stationed in the substation. So, this could be again busbars inside or could be the transformers or could be the high voltage cables.

So, this each of these equipment contribute to the magnetic field and typical example is shown here, the magnetic field caused by the cables or high voltage transformer busbars, could be a 33 micro tesla an example here. So, as the distance increases it gets reduced you can see and it goes on reducing, but still you will be expose to the magnetic fields in this area.

So, that clearance measurements have to be seen and safe planning for the people who are working have to be done in any in house located substations or a cellular buildings which are being adopted the high voltage substations are put up.

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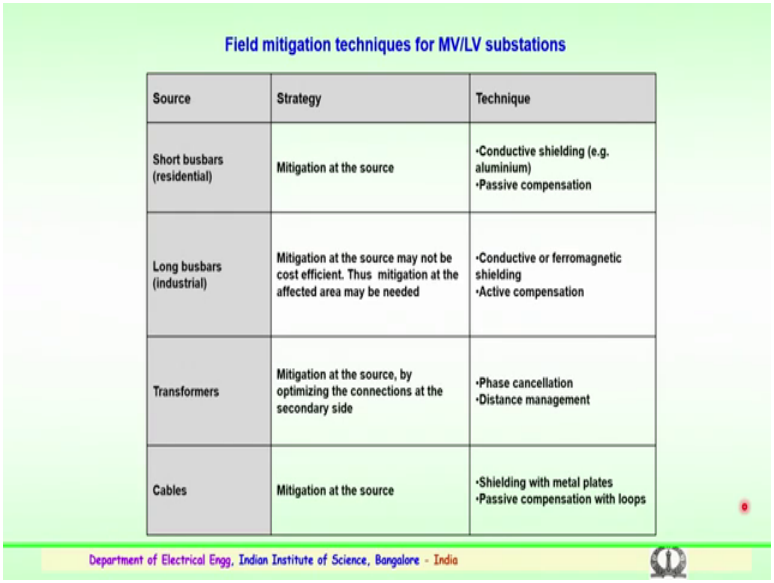

To the field mitigation techniques employed for the medium voltage and low voltage substations. So, these are the various sources that is assort.

Could be a busbars near the residentials and long busbars in case of industries, and the transformers and cables being the major equipments again the transformers depends upon the rating and the load which is it is being connected and the cables are also to be mitigated. So, strategy mitigation at the source level could be done, again mitigation at the source may not be cost efficient because busbars.

Thus mitigation at the affected area maybe needed that is where ever near the industry near the area has to be taken care. In case of transformers the mitigation for the electric and magnetic field at the sources that is by optimizing the connections at the secondary side could be reduced. Again for cables mitigation should be done at the source level. So, what are the techniques adopted in case of busbars in for the residential purpose.

So, conductive shielding example aluminium or copper or proper shielding could be done. And a passive compensation going in for loop type of arrangement could reduce the fields in the medium voltage or low voltage. For long busbars particularly for the

industrial sections a conductive or ferromagnetic shielding is advised, and again going in for active compensation could reduce the fields here.

For equipment like transformers the phase cancellation technique is normally adopted. And also the distance management the clearances will reduce the fields magnetic or electric fields. So, cables the shielding with metal plates are going in for passive composition with a loop arrangement will reduce the magnetic or electric fields in case of medium voltage or low voltage substations.

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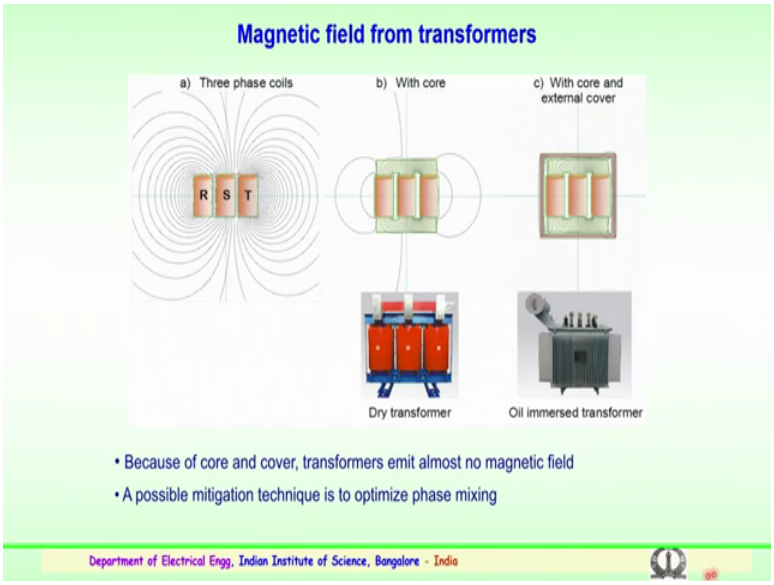

These are some examples from were the magnetic field could be generated from the transformer. It could be because of the core, it could be because of the transformer fields which could be emitted. So, some of the possible mitigation technique is optimize the phase mixing. So, phase mixing will try to help in case of the transformer, 3 core transformer to reduce the magnetic fields which are the generating from the transformer.

So, various types of transformer. So, here a proper techniques mitigation techniques should be followed before the equipment is being installed in the substation.

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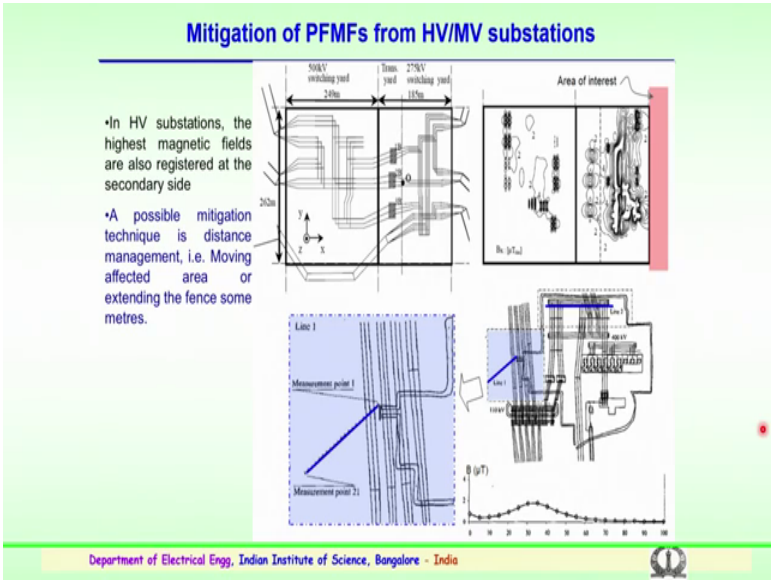

So, mitigation for frequency magnetic fields which are could be generating from high voltage or medium voltage substation we have seen for low voltage substation. So, as the voltage level goes up the current carrying capability of the conductors will be very high.

Ah and also the switchyard which compresses of a bigger area in comparison is of importance and were long busbars transformers and many switch gear equipments which are placed are also could generate the magnetic or the electric fields. So, the places particular in high voltage substations, the highest magnetic fields are normally registered at the secondary side of the equipment.

So, a possible mitigation technique is again the distance or clearance management that is moving towards the affected area or extending the fence that is clearance So that this fields could be reduced as the distance goes up you can see the magnetic field, as a distance goes up the field gets reduced. So, this is very important to be followed for the higher voltages substations both for a magnetic and electric fields.

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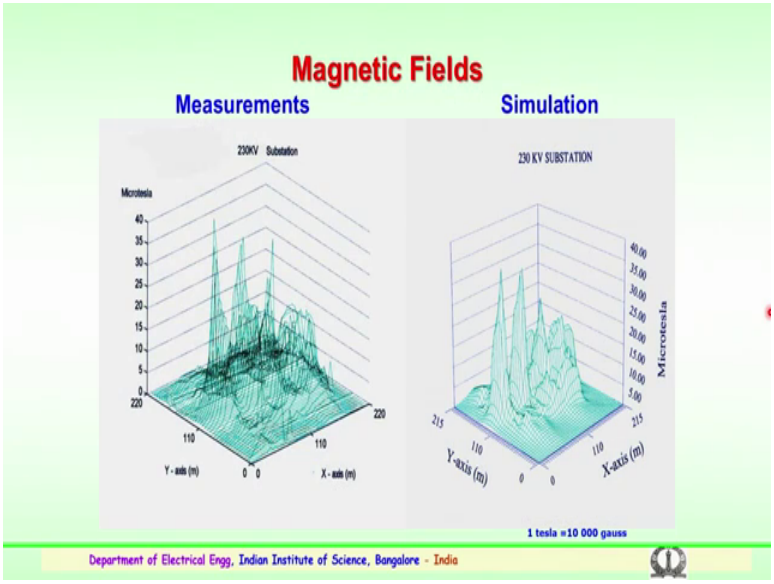

So, some of the simulations which have been carried out for various voltage levels in the substation are shown here, you can see the magnetic fields depending upon the distance for 230 kv substation, the magnitude varies.

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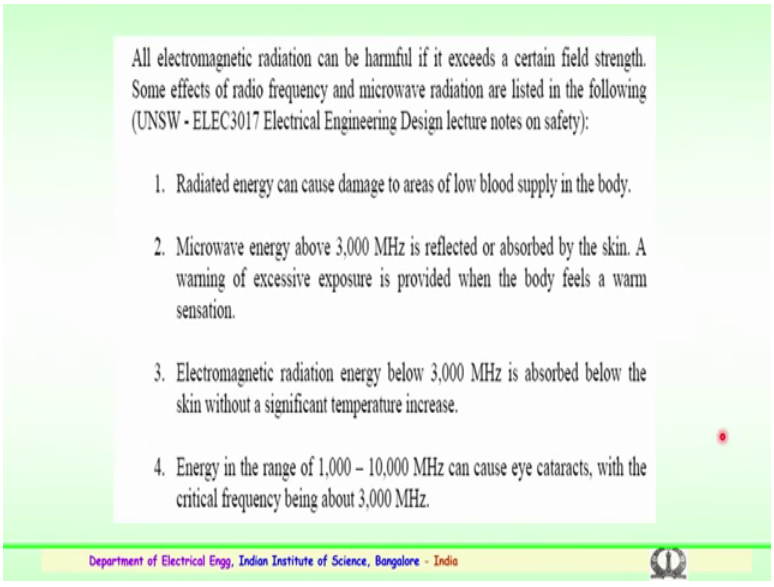

So, the all electromagnetic radiation has been available from the literature could be harmful if it exceeds a certain field strength specified limit is and exposure for long period of time.

So, some effects of radiofrequency and microwave radiation are also listed in the following lecture notes particularly on safety aspect. So, very important points to be considered. The radiated energy which when exposed for a long period of time could cause damage to areas of low blood supply in the body. The microwave energy above 3000 micro hertz, mega hertz is reflected or observed by the skin.

So, a warning of excessive exposure is provided when the body feels a warm sensation. So, proper measuring gadgets to be worn by the people who are working in the substations or near the vicinity of the electromagnetic fields, where the sensing devices should be such that it should be able give the information the fields which are being exposed.

So, the electromagnetic radiation energy, it is said that below 3000 megahertz is observed below the skin without a significant temperature increase. So, if it is below 3000 megahertz not much of issue. If energy is in the range of 1000 to 10000 megahertz, could cause eye cataract with the problems for the eye, with critical frequency being above 3000 megahertz. So, this is of a concern particularly for the frequency range of one 1000 to 10000 megahertz.

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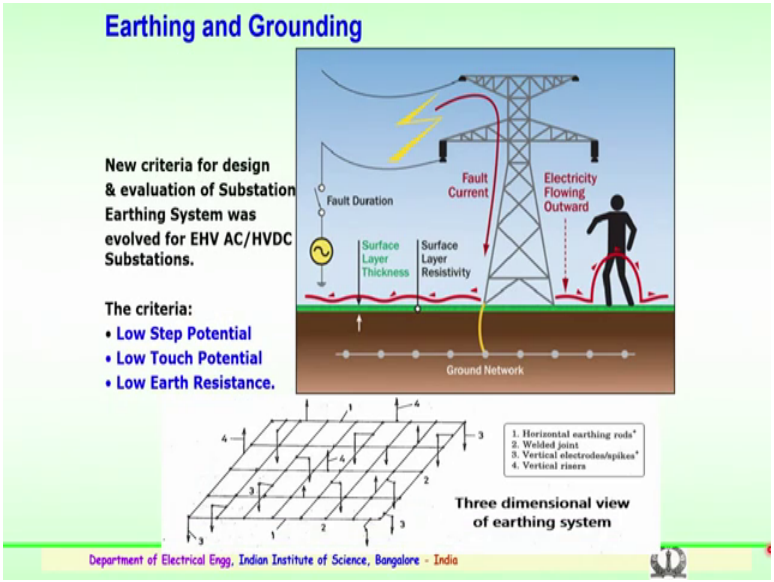

So, that was about the electric and magnetic fields in the substation it could be of high voltage substation or it could be of a medium voltage or low voltage substation. So, proper precautions are important proper conductor management the clearances and

necessary shielding will help to overcome the fields both electric and magnetic fields. We will look into the earthing and grounding aspects.

Again these earthing and grounding are very important in the substation. This could be because of the potential rice, because of several aspects. So, a proper design of the grounding or earthing system in the EHV that is extra high voltage AC or HVDC substations is essential for the safety and proper equipment protection. So, very important is the earthing or a grounding.

So, the earthing or grounding again depends upon various factors, it depends on the surface conditions the soil the surface resistivity, the current which is flowing into the ground, the fault current which could come because of the lightning or it could because of the electrical network malfunction. So, several of this aspects the ground or the earthing has to be properly connected to the ground network, where this has to be safely connected to the ground potential. So, that there is no damage to the equipment or the personal working near the substation.

So, this very important 3 points. The criteria for the earthing or evaluation of the substation grounding aspects is to see that it has to be low step potential, the grounding or earthing should provide a low touch potential and also low earth resistance very 3 important factors. Step potential earth touch and the earth resistance are very important in any substation.

So, several techniques or several methods or being followed for the earthing or grounding in substation, depending upon the voltage level depending upon the soil availability, depending upon the conditions the grounding or earthing is done. So, this is one of the example of the grounding mesh with a barring of grounding roads various types of schemes are available for grounding depending upon the voltage and depending upon the soil resistivity.

Say horizontal earthing rods or the welded type of joint mesh vertical rods sometimes with the spikes or the vertical risers. So, several types of combinations example is a 3 dimensional view of the earthing has been shown here. So, it is followed a proper design is being planned and conducted depending upon several factors in the substation.

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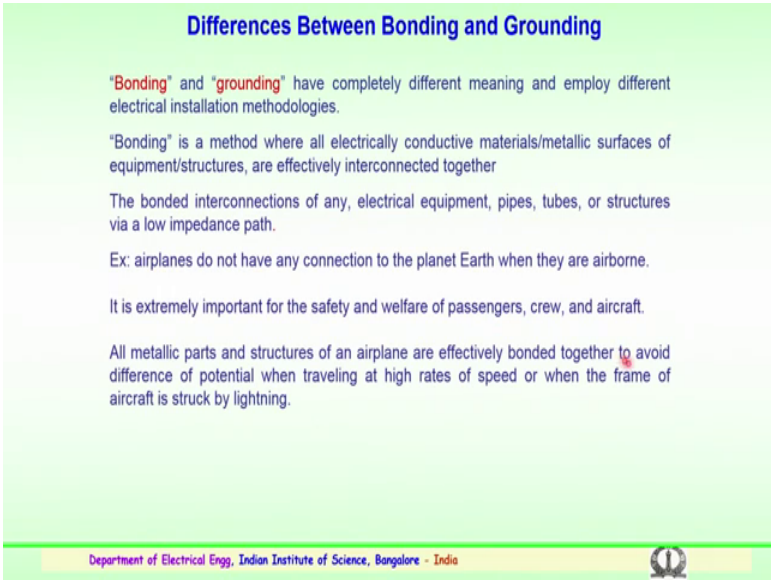

So, before going to the earthing or the grounding aspect. Information about the bonding which also hear that some of the instances. So, what is the difference between the bonding and grounding or earthing? So, bonding and grounding In fact, have completely different meaning and employ different electrical installation methodologies.

So, when you closely observe a bonding is a method where all electrical conductive materials or metallic surfaces. So, it could be conductive materials or metallic surfaces of the equipment or structures are effectively inter connected together. So, this is the point to be noted here all the metallic parts have to be properly inter connected. The bonded inter connections of any electrical equipment, like pipes tubes or a structures should be via a low impedance a path, the very should be very, very low resistive path.

So, this example of bonding could be seen in the aeroplanes. So, aeroplanes particularly do not have any connection to the planet earth. When they are airborne when the aircraft is airborne there is no direct ground connection between the aircraft and the earth. So, it is extremely important for the safety and welfare of the passengers crew the electronic components in the aircraft.

So, here all metallic parts the structure on the aeroplane or aeroplane are effectively bonded that is jointed and seen that mainly this jointed together to avoid difference of potential. That is when the structures are jointed together or properly brought together these are to be inter connected So that there is no difference of potential when traveling

at high rates of speed or when the frame is of the aircraft. Say during the aircraft in case if it is struck by lightning. So, there should not be difference of potential which I seen on the metallic structures.

So, this difference of potential could be will cause rise in potential and where it could be safety issue to the passengers or the control circuitry in the aircraft. So, that is the reason were the bonding is very important. So, the bonding inter connections of any electrical equipment or the tubes structures should be of low impedance path and there should be no be difference of potential near the connections.

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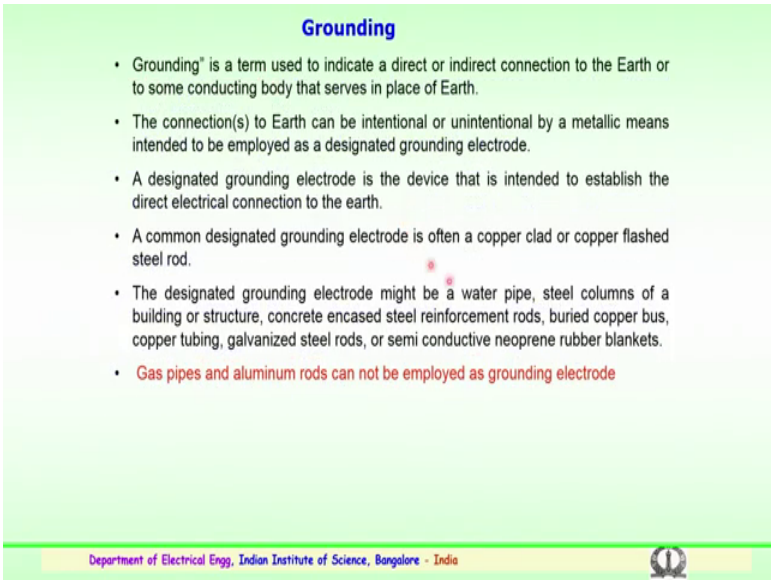

So, grounding or earthing this is a general term which is used to indicate a direct or indirect connection to the earth that is the mother earth what we called as a electrical personal. So, connecting to the earth or to some conducting body that serves in place of earth in some of the cases the grounding could be connected to a place which serves as a earth. So, the connections to the grounding or earthing can be intentional or unintentional by a metallic means.

This is intended to see the employed at a designated grounding electrode grids connected to the proper grounding electrode. The common designated grounding electrode is of normally employed is a copper clad or copper flashed or steel rod which is used for earthing or the grounding of the equipments. This grounding electrode which is used must be could be a water pipe or steel columns or a building or a structures.

So, the concrete encased that is the steel reinforcement rods could be buried copper bus or a copper tubing or a galvanized steel rods or a semi conductive neoprene rubber blankets. So, several of these grounded electrode could be then will could be connected to the grounding. The gas pipes it should be noted that gas pipes and aluminium rods cannot be employed as a grounding electrodes.

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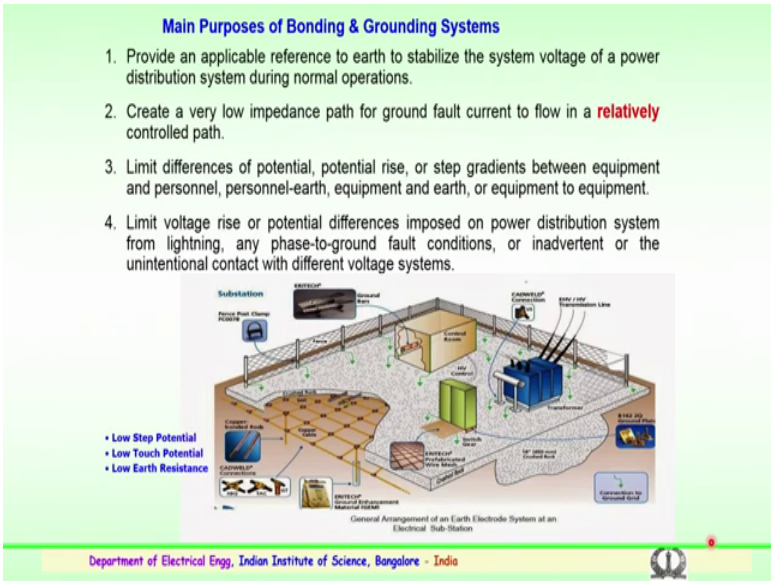

The main purpose of the grounding or earthing systems is to provide an applicable reference to the earth. To see that the entire system is stabilized of a power distribution under normal operation. So, during the normal operations rise in a potential is not to be observed, that is one of the main important aspect where the system should be stable and the reference to the earth is properly connected.

And the earthing or grounding should create a very low impedance path for the ground fault currents, in particular to see that the flow in a relatively controlled path. That is the fault current should flow through the ground which is designated ground which is connected to the equipment. And this grounding or earthing limit is the differences of potential particularly the rise in potential. Or the step gradients between the equipment and sometimes the personnel or it could be due to the personnel and the earth the step potential between the person and the earth or equipment and the earth or equipment to equipment.

So, several difference of potentials could be limited by going in for the proper earthing or the grounding aspects. And also the grounding or earthing will limit the voltage rise or potential difference imposed on power distribution system in case if there is a lightning strike on the building or on the power distribution towers. So, any phase to ground fault in case happens or inadvertent or unintentional contact with the different voltage systems the over voltages which are developed should be safely communicated or contacted through the connected to the ground to see the equipments do not get damaged.

So, very important aspects. So, the step potential or a low step potential should be maintained a low assistant fact the low touch potential and also the low earth resistance have to be maintained in a substation, for the proper functioning and seeing that there is no rise in potential which could the cause gradients and cause equipment or the personnel who are working in the substations, for the safer safety of personnel or the equipments.

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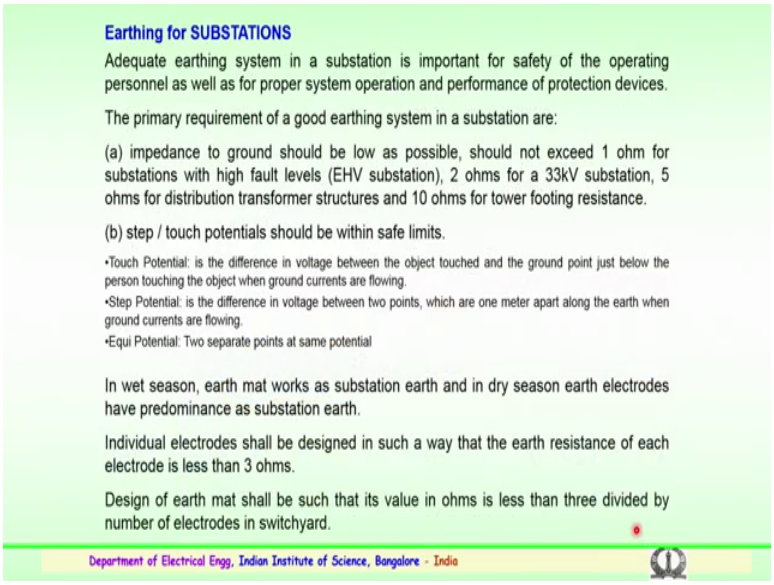

So, how earthing for a substations we have discussed. So, important points being in the substation to be maintained are the low step potential. The low touch potential and low earth resistance are 3 important factors to be considered. So, adequate earthing in a substation is very important as mentioned for safety of the operating personnel as well as for the proper system operation and performance and protection of the equipments in the substation the equipments and the protective devices.

So, several of this have to be considered. So, the primary requirement of good earthing system in any substation are to see that the important conditions that impedance to the ground should be as low as possible, should not exceed more than one ohm as specified by the standards, for the substations with high fault levels particularly for extra high voltage systems. In case distribution type of substations are typically 2 ohms for 33 kv or a 5 ohms for distribution transformer structures and 10 ohms for tower footing could be permitted by the standard.

So, as a voltage level goes up very minimal or the should offer a low impedance very, very low impedance as possible the second important is the step or a touch potential should be within safer limits. So, this touch potential as mentioned is the difference in voltage between the object touched which the we touch and the ground point. So, between the ground point and the object which is being touched is known as the touch potential.

So, just below the person in case if he is touching the object with the ground currents are flowing. And the step potential could be defined as the difference in the potential between 2 points. What are the 2 points? Which are one meter apart from the earth when ground currents are flowing. So, this is the step potential and the equi potential being the 2 separate points at a same potential any 2 contacts which are at the same potential.

So, usually during the wet or the rain conditions the earth mat in a substation works in a substation, and in dry season the earth electrodes have predominance as substation earth. So, the proper planning of the earth mat in a substation is very important. And also the individual electrodes which are used for the earthing should be designed in such a way that earth resistance of each of the electrode which is being used should not be less than 3 ohms as per the specification, the value could be still reduced as a voltage levels increase for UHV and EHV systems.

So, the design of earth mat should be planned in such a way the value in the lower ohms is less than the value which is divided by the number of electrodes could be employed in the switchyard. So, earthing or the grounding in substation is a very important arrangement which has to be made for all the equipments and the personnel who are working for the safety concerns.

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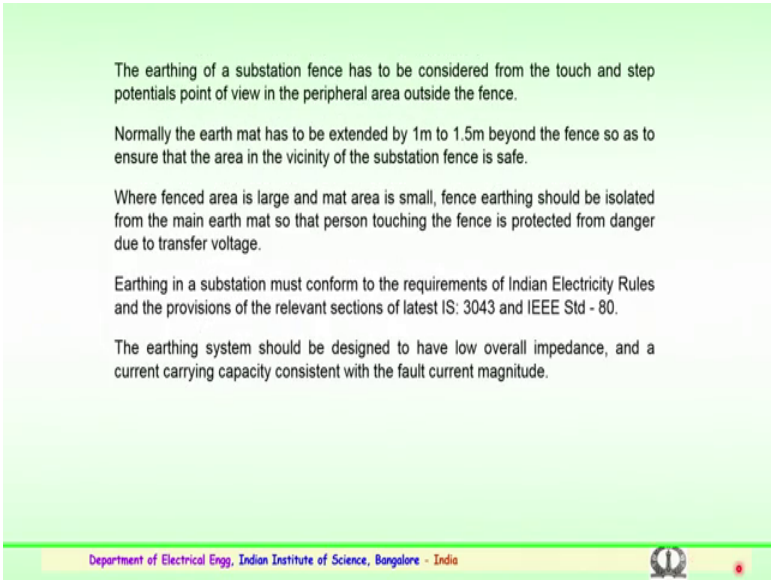

So, the earthing of a substation fence has to be considered in case of the touch and the step potential. Here the point of view is the periphery area outside the fence. So, usually the earth mat could be extended by one meter to 1.5 meters beyond the fence, this will help to ensure the area near the vicinity of substation fence is safe for the operation personnel.

So, when the fencing of the area is a very large, and the earth mat area is very small, the fence earthing should be isolated, very important. And the main earth that is a main earth which is being connected to the equipments and the entire substation. So, that the person touching the fence is protected from the danger due to the transfer of voltage or because of the step potential were you could see.

So, the earthing or a grounding in a substation has to be confirmed to the requirements of the Indian electricity rules, or the international electricity rules and these regulations and the provisions of the relevant sections referred in the Indian standards 3043 and also I triple e standard 80 are clearly mentioned for the requirements for different voltage levels.

So, the earthing system should be designed to have a low over all impedance, very important is very, very low over all impedance and a current carrying capacity consistent with the fault current magnitudes. So, for which could be generated due to the faults in the network system.

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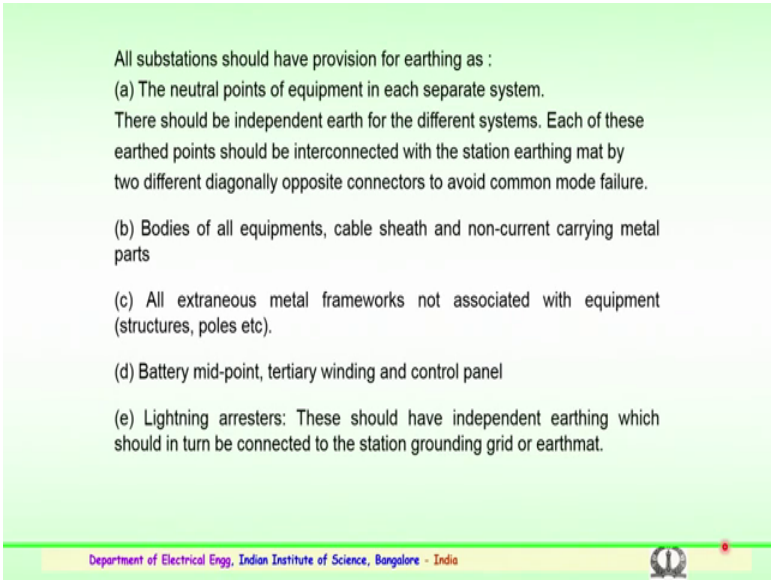

So, all the substations it could be a low voltage medium or a very high voltage should be able to have a provision for earthing or a grounding. And it should be seen that the neutral points of the equipment in each separate system are maintained.

There should be independent earthing for the different systems, and each of these earth point should be inter connected with the station earthing mat by 2 different diagonally opposite connectors, mainly to avoid common mode failures. So, all the bodies of the equipments, any equipments systems which are in the substation the cable sheath and also the non current carrying metal parts have to be properly earthed.

Any extraneous metal frameworks which are not associated with the equipment structure poles etcetera are also to be earthed. The battery midpoint the tertiary windings and the control panels have also the provisions for earthing. The important point is the lightning arresters which are very important components in the substation. This should have an independent earthing which should in turn be connected to the station ground grid or the earth mat which is existing in the substation.

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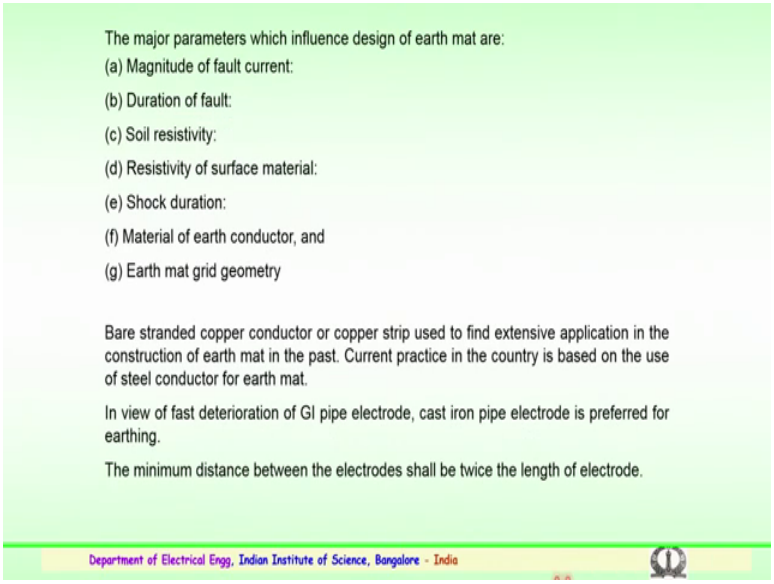

The major parameters which influence the design of earth mat are very important parameters, are the magnitude of the fault current. Again the magnitude of the fault current depends on the voltage level of the substations which is it is operating. And the fault which an equipment sees, the duration of the fault, the soil resistivity of the area, the resistivity of the surface material, the shock duration the type of shock, and the material of earth conductor which has been used, and the earth mat geometry which has been used in the substation.

So, several of these parameters influence the design of earth mat of a substation. So, any bare stranded copper conductor or copper strip which is used to find extensive application in construction of earth mat in the past have been used, presently the practice in the country is mainly based on the use of steel conductor for the earth mat. This could be because of the economic aspects.

So, in view of fast deterioration of the galvanized iron pipe electrode the cast iron pipe electrode is preferred for the earthing. And also the minimum distance between the electrodes shall be twice the length of the electrode that is the point to be noted here.

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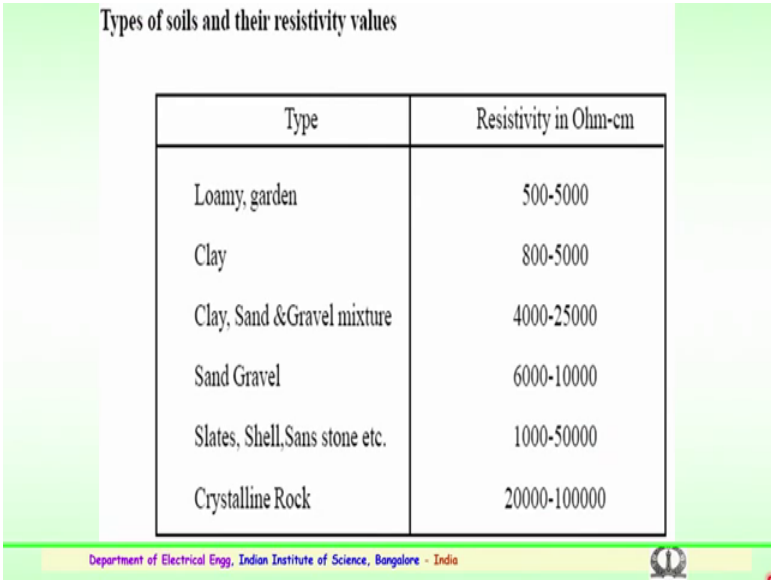

Ah this gives a table of the resistivity in ohm centimeter for various soils which during the substation planning have to be considered in case of the different type of soils.

It could be a clay a clay sand a gravel mixture sand gravel slates crystalline rock. So, several of the type of soils are available and the resistivity in ohm centimeters for this related types are also given here in case of clay the resistivity in ohm could ohm centimeter could be 800 to 5000 similarly for a crystalline rocky areas the resistivity in ohm centimeter could be 20000 to 1 lakh.

So, suitable planning and suitable grounding aspects have to be chosen in the areas pertaining to this in case the substations are being constructed at the areas of the soils depending upon the soil the proper grounding has to be planned.

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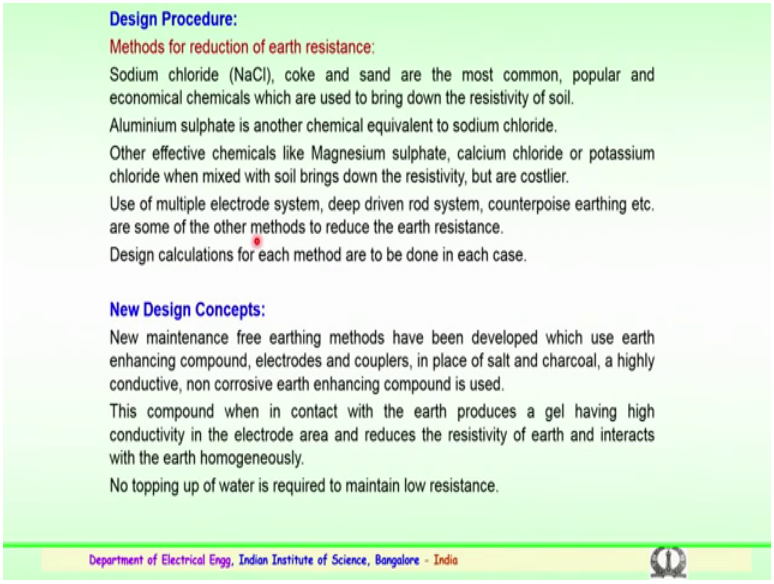

So, how the design procedures are adopted for reduction of the earth resistance. So, we will discuss some of the methods for reducing the earth resistance apart from the general design aspects and the material which is being used.

So, the earlier method of using the reduction for earth resistance is typically the sodium chloride salt which is generally used for a long period of time. Coke and sand that is a coal and sand are the most common and a popular and most economical chemicals which are used to bring down the resistivity of soil. So, in any earlier substations or for residential grounding the simplest mechanism will be the salt coal and the sand at different layers this is the popular and economical method which is being used.

Later the aluminium sulphate is another the chemical equivalent to sodium chloride this is also being used. The other effective chemicals like the magnesium sulphate. The chemical sorry calcium chloride or a potassium chloride when mixed with soil this will bring down the resistivity. But these magnesium sulphate calcium chloride or potassium chloride could be costlier in comparison to the sodium chloride or the other salts.

So, the use of multiple electrode system, deep driven rod system or going in for counterpoise earthing etcetera. Are some of the other methods which are normally followed to reduce the earthing resistance. So, the design calculations for each method are to be done for each case by case aspects, depending upon the soil depending upon the area where the substation is being constructed.

Some of the new methods or new design concepts or to reduce the earthing resistance are being employed by using a new maintenance free earthing methods which have been developed recently. So, this use earth enhancing compounds new type of electrodes and couplers in place of the salt like sodium chloride coke or sand.

So, this new type of the compounds have a high conductivity and these are non corrosive earth enhancing compounds which have been which have being used recently, this compound when in contact with the earth. So, produces a gel having high conductivity in the electrode area and further reduces the resistivity of earth and interacts with the earth homogeneously.

So, very important the compounds which are being employed will bring down the resistivity of the soil and also helps in proper more conduction and sees that the minimum resistance is offered to the fault currents. So, here important point no topping up of water is required to maintain low resistance. Like earlier methods where the ground electrodes or ground rods regular water watering to the ground is required here does not need to go in for the regular topping of water.

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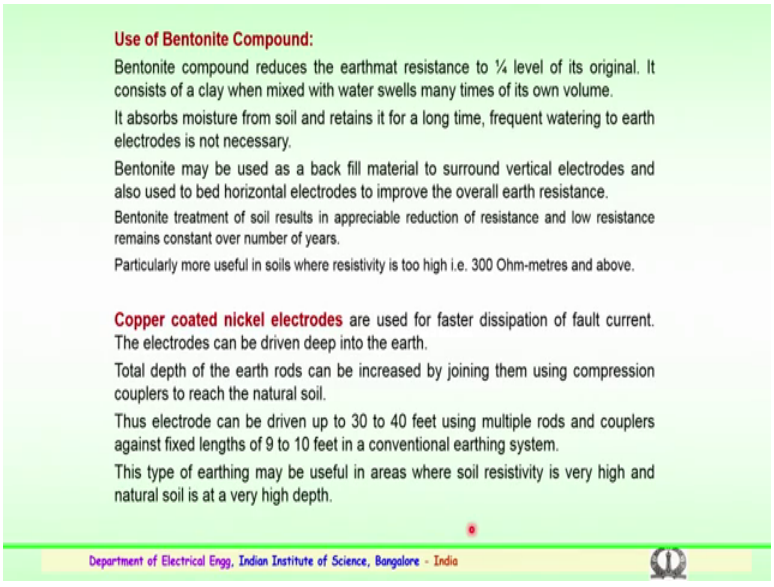

So, one of the method is to use bentonite compound again this compound is a recent method which is being employed, to reduce the earth mat resistance to one fourth level of it is original. So, this bentonite compound consists of a clay when mixed with water swells many times of it is own volume. So, important property of this bentonite

compound this compound will absorb moisture from soil and tries to retains it for a very long period of time.

So, here again frequent watering to earth electrode may not be necessary, that is one more advantages. So, bentonite may be used as back fill material to surround the vertical electrodes, and also could be used to bed horizontal electrodes to improve the overall earth resistance. So, this treatment of soil results in appreciable reduction in the resistance. And low resistance remains constant over number of years very important advantages for going in for this compound.

Particularly more useful to be using this bentonite compound in soil where resistivity could be very high, in the order of 300 ohm meter or above it could be of rocky areas or some areas where high resistance of the soil is offered. So, there other method of using the reduction of the earth resistance is by going in for copper coated nickel electrodes.

So, these are used for faster dissipation of a fault currents. The electrodes could be driven deep into the earth. And the total depth of these earth rods which are of nickel electrodes copper coated nickel electrode can be increased by joining them using compression coupler to reach the natural soil. So, thus the electrodes could be driven up to 30 to 40 feet in general by using multiple rods or couplers against fixed lengths anywhere between 9 to 10 feet in a conventional earthing system.

So, this type of earthing system may be very useful in areas where soil resistivity is very high. And the natural soil is at a very high depth. So, in such cases going in for the nickel coated copper coated nickel electrodes will be very useful to reduce the earth resistance in the area.

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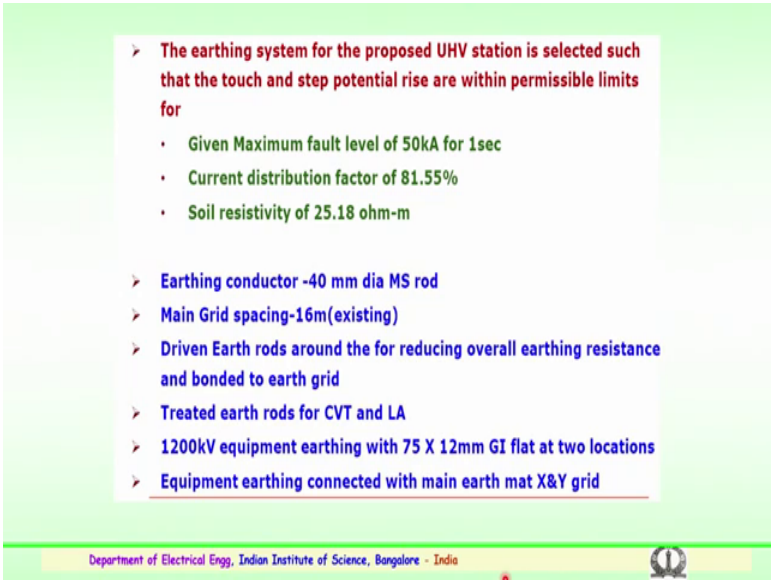

So, the earthing system for the UHV or ultra high voltage station is normally selected such that a touch and the step potential rise are within the permissible limits.

Ah say for a given a maximum fault level of 50 kilo amps for 1 second the current distribution factor of 81.55 percent and the soil resistivity of a 25.18 ohm meter. For such case the earth conductor should be of 40 millimeter dia mild steel rod. The main grid spacing should be 16 meters which could be of existing.

Then the driven earth rods around the around for reducing overall earth resistance and bonded to the earth grid. These should be earth rod should be treated for the CVT and connected to the lightning arresters or current voltage transformers. In case of 12 hundred kv equipment earthing with 75 by 12 mm galvanized iron flat could be employed for 2 location 2 locations and the equipment which is earthing connected with the main earth mat and both x and y grid should be followed, it is a very important as for the UHV substations. So, we will stop here and will continue.