Advances in UHV Transmission and Distribution
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Lecture – 24
Types of Substations, comparison

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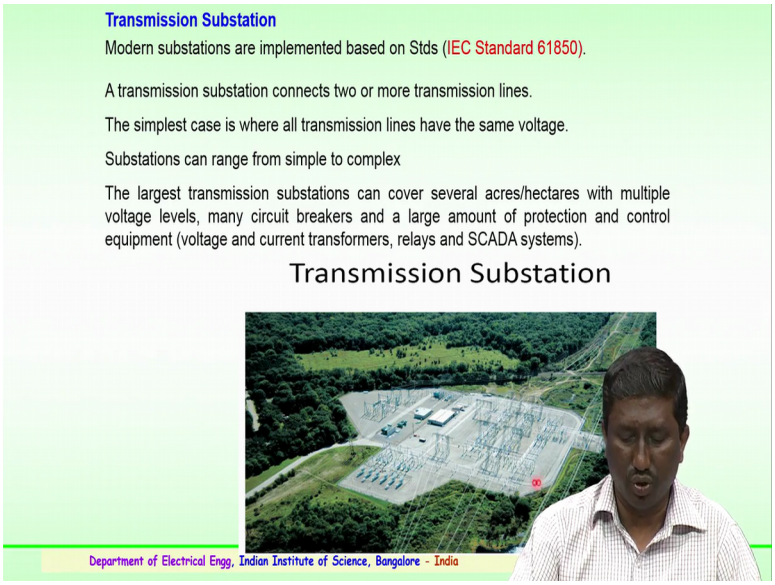

So, what is this transmission substation? Again transmission there are three types of substation which are being classified, one is the transmission, the second being the distribution substation and the third being the collector substation; we will discuss very briefly about each of these substations. So, transmission substation we know that the modern substations are implemented based on the standards which are being prescribed, it could be international standard IEC; Electrotechnical Commission, international technical standard; reference number 61850, this applies to the transmission substations.

We also have other rules laid out by the respective in the Indian standards also. So, as per The Central Electricity Authority guidelines; this substations are implemented and constructed. So, a transmission substation connects generally two or more transmission lines, so that is the point. The simplest case is where all transmission line have the same voltage, if the transmission substation could be operating at same voltage say 400kV or a 765kV or 220kV and so on; simplest case. But the substation can range from simple to complex, so this same substation it could receive a 765 and it could also have a 400kV

out lines so on. So, there could be a different level of voltages which are operating and it could be a simplest to the complex substation; the transmission substation.

So, the largest transmission substation could cover several acres or hectares with multiple voltage levels which could include many circuit breakers and a large amount of protection and control equipments; this again protection in control equipments consists of the voltage transformer, the current transformer, several relays; it could involve the SCADA system and communication network.

So, the typical transmission substation is shown here consisting of different type of a circuit breakers, the protection equipment, the control equipment and the control arrangement which has been done for a typical transmission distribution. This could expand over a wide area, could be having several acres; few acres (Refer Time: 02:57) of acres depending upon the voltage level and depending upon the complex nature of the voltages which are being considered.

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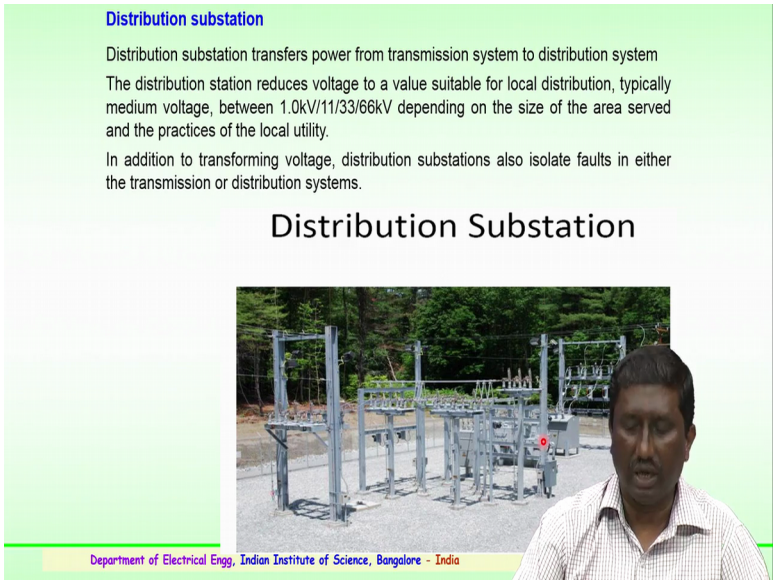

So, second is the distribution substation again the substation distribution; the main function of the distribution substation happens to be to transfer the power from the transmission substation to the distribution substation. So, the distribution substation reduces the voltage to a value suitable for the local distribution. So, this local distribution typically medium voltage levels anywhere between 1kV to 66kV; 1, 11, 33 or a 66kV, again this defines mainly on the size of the area which is to be served, where the loads

have to be catered and also the practices which are being carried out by the local utility or electricity authorities of the local state or district level.

So, in addition to the transforming voltage the distribution substation also isolate faults; that is very important in either the transmission or the distribution substation. So very important, so distribution substation not only caters to the local requirement anywhere between 11, 66 to the 1kV and it also tries to isolate the faults which could happen because in the transmission or the distribution systems.

This is the typical example of a distribution substation, again this consists of the various components associated in the substation like the protection of CTE's, the current transformer, the potential transformers, the equipment which protects like the surge arresters; you have a various relays and all these aspects here and the transformer that is very very important.

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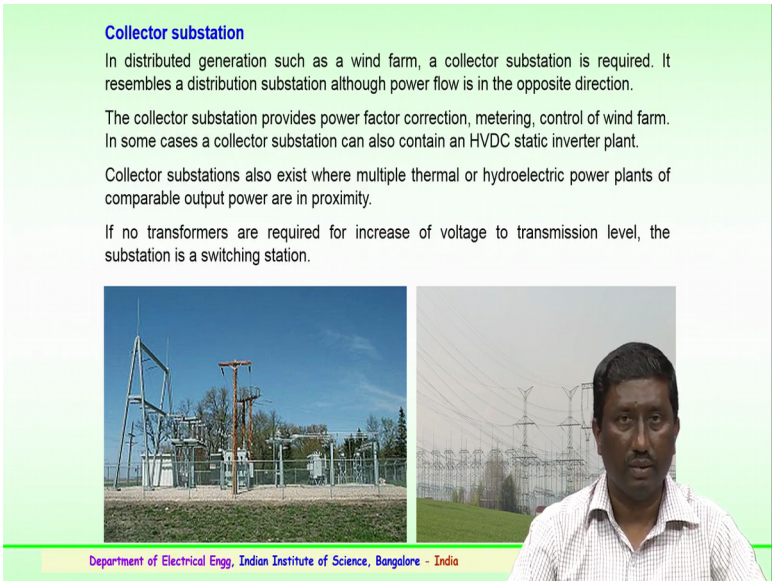

The third is a classified as a collector substation, this collector substation is basically in distributed generation; it is being such as the wind farm, here this type of substation is being seen or a adopted, where a collector substation is required. It similarly resembles like a distribution substation, although power flow in this is in opposite direction. So, here the point to be noted is because the collector substation provides a power factor correction and also metering the control particularly for the wind farms and in some cases a collector substation can also contain a high voltage DC, a static inverter plant.

So, the collector substations do exist where multiple generations like the thermal or hydroelectric plants or comparable output power are in the proximity; in such cases, the collector substation play an important role in combining this generating plants and trying to transmit the requirements of the power to the required loads. So, if no transformers are required for increase of voltage to the transmission level, the substation is generally termed as a switching substations; so, in case only activity where the loads are to be catered in case it is known as a switching, it is not the collector substation.

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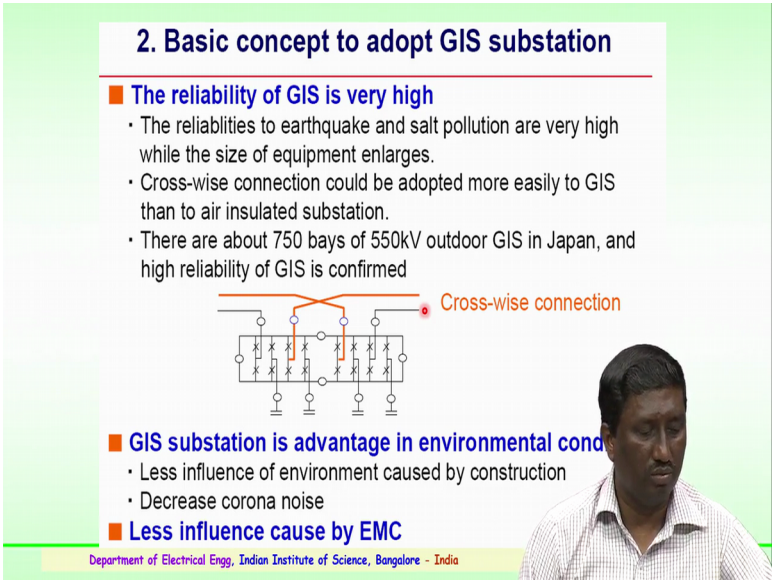

So, next we have discussed about the air insulated substation; all the previous information which have been discussed is a air insulated substation. You can see this is a air insulated in the since open field where the equipment are exposed to the atmosphere, it could be distribution, it could be transmission substation, it could be collector substation or it could be switching station, so these are in the atmosphere; open air atmosphere.

So, now the advancement in technology has seen that the substation, the compactness of substation, the compactness of the equipment used for substation has been advanced which has helped particularly in the areas where the space is a constant. So, in such cases the gas insulated substation is being widely accepted and widely being adopted; very important at various voltage levels. So, some of the basic concepts for adoption of the

gas insulated substation is classified as mainly because of the reliability of the gas insulated substation is very very high.

So, this reliability to earthquake and for the pollution or a contamination because which the air insulated substations are prone; are very high, so while the size of the equipment also enlarges. The crosswise connection could be adopted more easily; see here in case of air insulated substation, the clearance have to be followed and minimum clearances have to be maintained; whereas in gas insulated substation, you can see here anywhere the crosswise connections could be adopted because sulfur hexafluoride is insulating gas and the clearances are completely or reduced to a drastic level and the operating for the crosswise connection could be adopted more easily and compared to the air insulated substation is very important point and there are about several more then 750 bays of 550kV outdoor GIS; only in Japan and high reliability of GIS is already confirmed.

So, several countries including India are being going in for gas insulated substations. So, we have several gas insulated substations which have come up in the last decade in the country at various voltage levels and they are functioning very well, so that is the point to be considered. So, the gas insulated substation is advantages particularly in the environmental conditions because it has less influence on the environment caused by the construction and this going in for gas insulated will decrease the corona noise, which was noticeably seen in case of air insulated substations and second important point being the less influenced or less noise caused by the electromagnetic compatibility, so less EMC this is very important point to be seen.

So, the basic concept to adopt gas insulated substation should be made is to see that it is compact and as possible to see, to reduce the construction cost of the substation that is very important.

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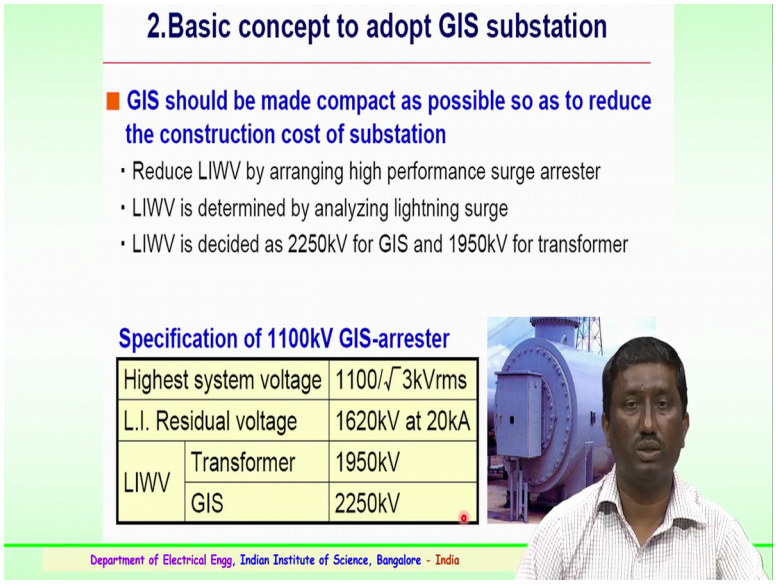

And going in for this; so, to reduce the lightning impulse withstand voltage, a lightning impulse withstand voltage by arranging high performance surge arrester could be done and also is determined by analyzing the lightning surge. So, this can be again considered to reduce the cost. So, lightning impulse withstand voltage is decided as a 2250 for gas insulated substation and 1950kV for transformer for a particular voltage level of mentioned shown here in the table.

So, specifications when you consider 1100kV GIS arrester; the highest system could be 1100 divided by root 3 and lightning impulse residual voltage will be 1620kilo volts at; when the current is passed 20 kilo Amps. So, lightning current of 8 by 20 micro seconds is passed to the disk or arrester of 1100 kV.

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So, 1620 should be the residual voltage and the lightning impulse withstand voltage in case of transformer should be 1950kV and the gas insulated substation should be 2250; 2250 kilovolts are the specification for GIS. So, this is the typical gas insulated substation which is being seen here; it consists of a transformer, gas circuit breakers or the bushingm gas surge arresters. So, all are sulfur hexafluoride gas as a insulating media which reduces the entire cost and it is very very compact.

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This is one of the example of a 400 kV GIS station, which also several switchgear and bus duct. So, a very compact size of 400kV typical substation will have several acres in the open air, here it is less than one-tenth of the required area in case of the air insulated substation.

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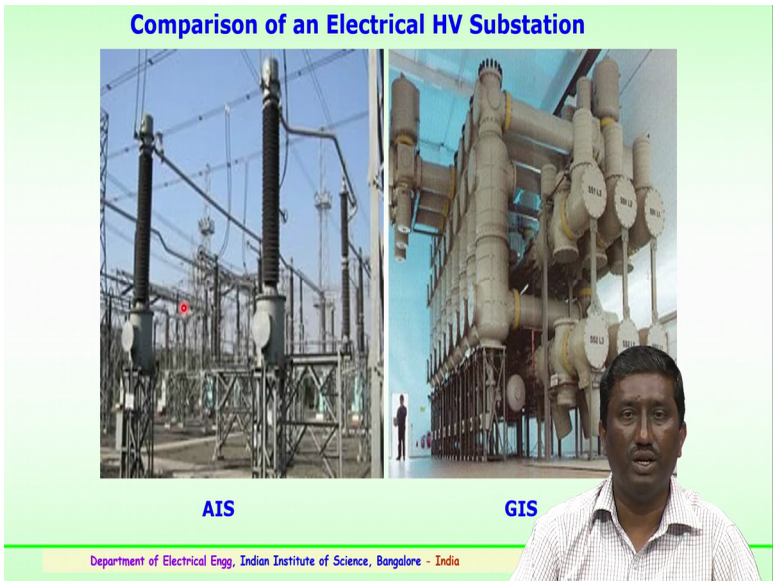

So, this is similar comparison of an electrical high voltage substation, you can see this air insulated substation which has exposed to the atmosphere lot of clearances and several complicated arrangements have to be carried out. Whereas for the gas insulator substation, it could be very compact and with the help of the sulfur hexafluoride gas it could be made compact.

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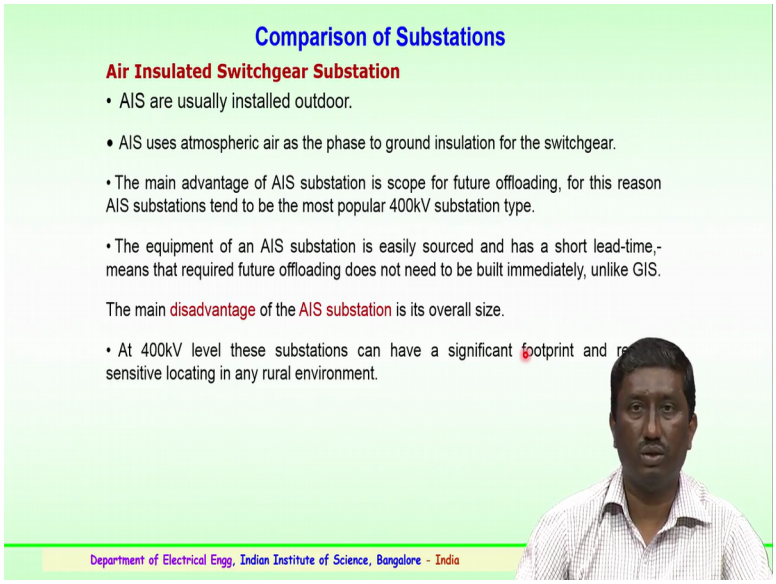

So, we will compare various substations importance comparison of air insulated switchgear substation. So, generally air insulated substation are installed outdoor that we have discussed. So, air insulated substation uses atmospheric air as the phase to ground insulation, so air is basically used as an insulation; that is the clearance from the metal to the ground is being maintained with the insulating media being the surrounding air of for any switchgear.

The main advantage of going in for air insulated substation; is the scope for future offloading, in case the substation has to be upgraded from a particular voltage level to the higher voltage as it is not a difficult arrangement could be made for the up gradation. So, for this reason air insulated substation tends to be more popular in case of 400kV substation or higher voltage levels and the equipment of an air insulated substation is easily source because several players are available, who can supply the equipment pertaining to the air insulated substation that could be switchgear circuit breakers, isolators, surge arresters, transformers.

So, basically many manufactures are available in the country and abroad where you could get the equipment without much of the difficulties. So, and also has a short lead time means that the required future offloading does not need to built immediately like the; unlike the gas insulated substation, so this is several advantages going in for air insulated switchgear. The main disadvantage of going in for air insulated substation is

mainly because of its overall size; see example at 400 kV level; these substation can have a significant footprint and could require sensitive locating in any rural environment, but in the places of thickly populated and the places in the metro cities; getting the land for the substation could be of very difficult or it could be tedious job for getting the land.

So because of the high cost involvement; so, the air insulated substation building particularly in the thickly populated and where the land prices are very high, could again increase the cost of the substation.

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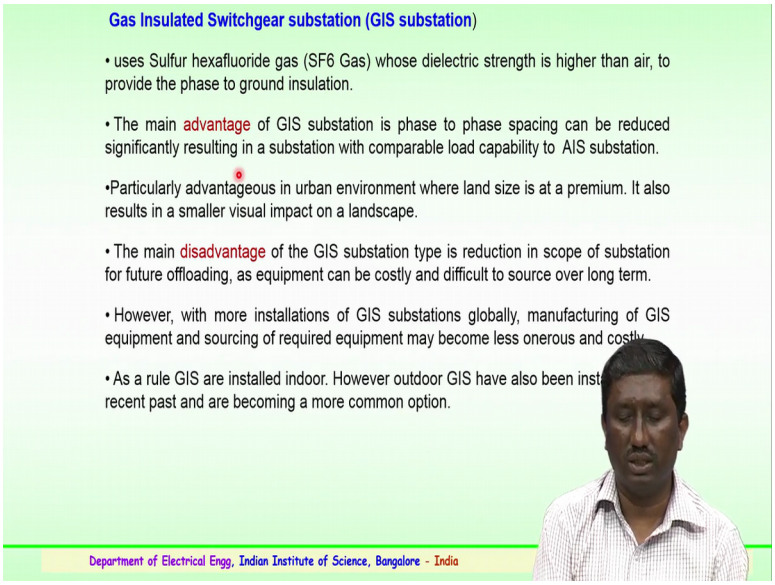

So, gas insulated switchgear substation mainly as earlier mentioned, uses sulfur hexafluoride gas as the insulating; SF6 Gas as a insulating medium. The dielectric properties, the insulating properties are higher than the air and they provide the phase to ground insulation here. So, cylinder containing the SF6 Gas with the conductor at high voltages and filled with the sulfur hexafluoride gas acts as a dielectric or a insulating media, to provide the clearances required to phase to the ground insulation.

The main advantage of going in for gas insulated substation, is the phase to phase spacing can be reduced significantly resulting in a substation with comparable load capability to the air insulated substation. So, that is the one of the main advantage; the spacing could be reduced, this further reduces the load and the comparable size of the substation and particularly this is advantageous as mentioned in urban environment and the place where the land size is at a premium or a very cost.

So, in such cases it also results in smaller visual impact on the landscape that is a very very important point. But the main disadvantage of the gas insulated substation type is a reduction in scope of the substation for future offloading. As the equipment can be costly and again difficult to source over long period of time, so gas insulation substations have to be properly planned for future requirement, else immediate going in for change or going in for the upgradation would necessitates the economical constraints; that is the very important point to be considered.

However, with several insulation as mentioned of gas insulated substation; coming up globally and also at the country level in India. Several utilities are installing the gas insulation substation up to 400kV levels. So, presently several manufacturers are available with the gas insulated substation equipment and in future the sourcing of this required equipment may become a less (Refer Time: 18:45) and also less costly, that is it could be more economical in future because of number of manufacturers going up.

So as a role gas insulated; substation are generally installed in indoor that is the very important point, it is not an outdoor substation. However, outdoor GIS also has been installed; in the recent past and again they are becoming a more common option. So, both indoor and outdoor and there are also hybrid substation, which partially the transformer being in the outdoor yard and the GIS technology for the switchgear and the best at. So, air insulated, gas insulated and also hybrid insulted substations are being constructed depending upon the economic considerations of the utilities.

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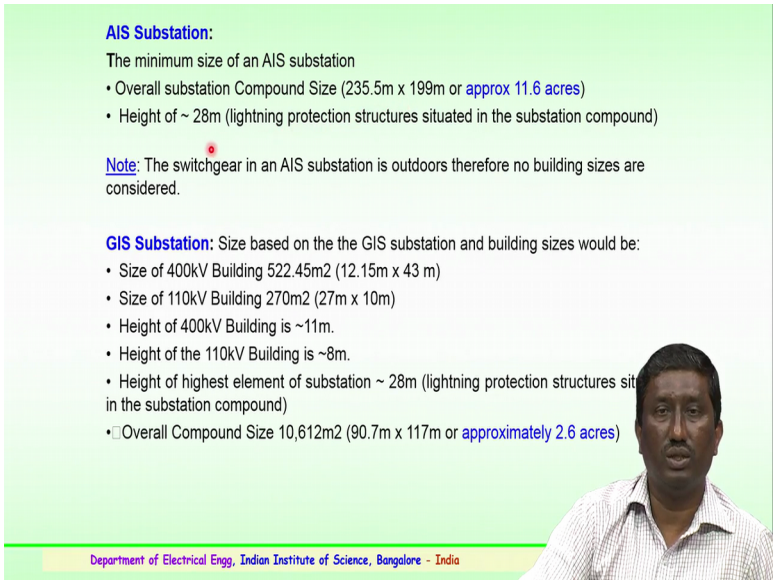

So, air insulated substation; the minimum size of an air insulated substation, overall substation compound these are some specifications for a 400kV level, when you compare both air insulated and gas insulated substation. You can see, the overall substation size could be anywhere 11.6 acres is a requirement for the land to build a 400kV substation. The switchgear is a air insulated and outdoors therefore, no building sizes are considered here because of the entire switchgear is kept in the open yard and only the control arrangement is the building which is to be housed the control gear and the protective relays and so on.

Whereas, in gas insulate substation; the size is based on the gas insulated and the building sizes would be for 400kV typically is 12 meter by 43 meter could be sufficient for the 400kV GIS station. The size of 110kV building could be only 27 by 10 meters and height of 400kV building is generally 11 meters; whereas, here if you see the compound and the height is 28 meters; here it is lesser than 50 percent of the height which is required for the air insulated substations.

So, the overall size when you look approximately for the gas insulated substation is typically around 2.5, 2.6 acres of land is required of for a 400kV gas insulation substation, whereas for a air insulated anywhere between 11.6 to 12 acres is a requirement, drastic reduction more than 5 to 6 times in the overall land availability going in for GIS substation.

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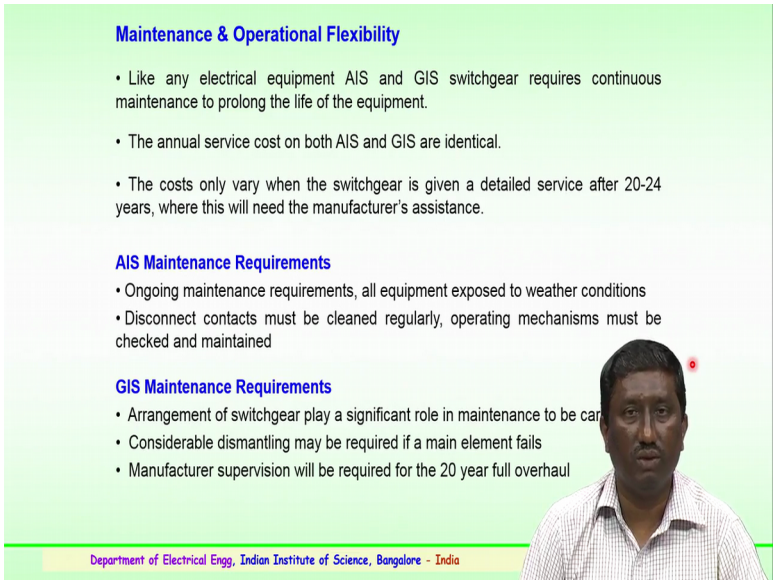

About the maintenance and operational flexibilities very important point, so like any electrical equipment; it could be air insulated or a gas insulated switchgear. These require continuous maintenance very important because the maintenance done normally to prolong life of the equipment or the insulation of the equipment so that it last for a last period of time in the service.

So, the annual service cost comparison for both air insulated and gas insulator are identical in nature. The cost only vary; with the switchgear that is given in retailed service maybe after 20 to 24 years where this will need the manufactures assistance. So, the annual maintenance cost remains both are same. In case of air insulated substation, the maintenance requirements could be for the ongoing maintenance of the equipments which are exposed to weather conditions or a climatic conditions and in case of circuit breakers, the disconnect or isolated disconnect contacts must be cleaned regularly and the maintenance has to be carried out regularly for the operating mechanisms.

And also must be verified and maintained auto regular intervals that is very important, in case of GIS; similar maintenance requirements. The arrangement of switchgear play a significant role particularly in the maintenance to be carried out and also the considerable dismantling are may be required in case if a main element of an equipment fails.

So, here the point to be noted in the air insulated substation, the local knowledge or the local idea could be available and the problem could be solved but whereas in case of GIS

maintenance, there is a requirement from the personnel, from the manufacturer as the supervision will be required for the 20 full years, as the manufacturer presents is of at most importance, particularly in case of equipment or any element failures the changing of the equipment or the elements has to be done in the presence of manufacturer, supervision very important point to be considered.

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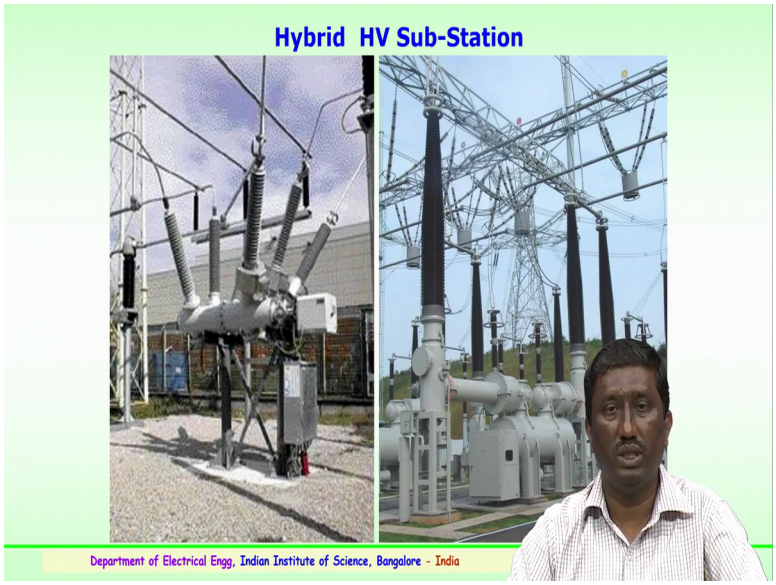

So this shows the comparison of a hybrid and hybrid high voltage substation, so gas insulated substation, air insulated we have seen. So, hybrid is a combination of the air insulated and the gas insulated; the important point being again it reduces the economy to a certain extant going in for full GIS could be more costly. So, in some of the cases transformers could be installed in the open yard, that is the outdoor and rest of the equipment could be gas insulated.

So, this drastically brakes down the cost of the transformer which could be of gas insulated GIS. So, this type of substation are also being considered and being established by the utilities at different parts of the country and also the globe; this is the typical example of hybrid type of substation.

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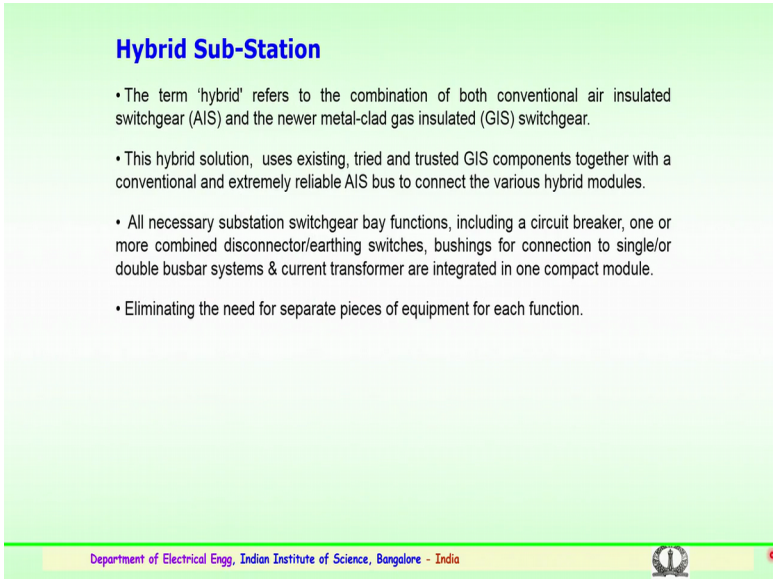

So, hybrid as mentioned again the term refers to the combination of both the conventional that is the air insulated, switchgear and the new one that is the metal clad or the gas insulated switchgear which we were discussing.

So, the hybrid solution uses existing tried and trusted gas insulated components together. So, very important it is both technologies with conventional and also extremely reliable air insulated bus to connect the various is hybrid modules. So, here all the necessary substation switchgear including the bay functions and circuit breakers are combined in one or more form like a disconnected or earthling switches, the bushing to the connection could be of single or double busbar systems and the measurement like the current transformer, the potential transformers could be integrated into one compact module. .

So, this is the hybrid arrangement and it is seen that the eliminating the need for a separate pieces of equipment for each function is normally done.

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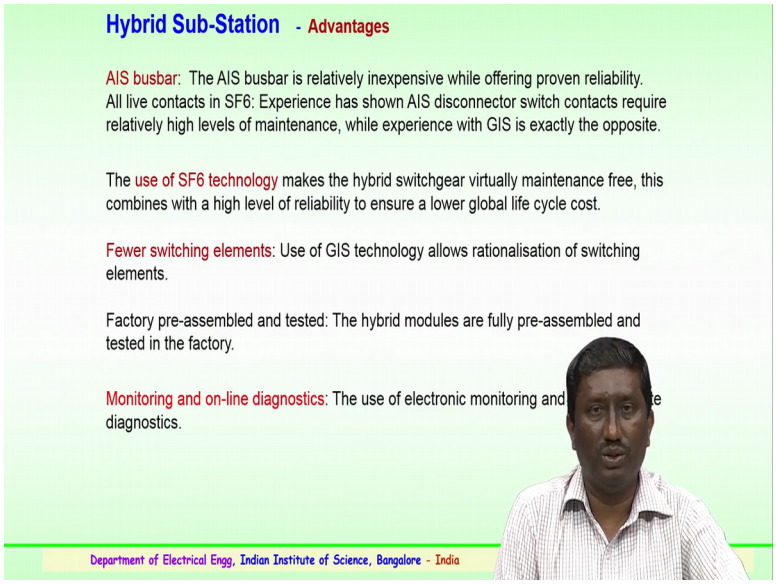

So, what are the advantages of going in for this hybrid substation, so hybrid substations you have the air insulated substation busbar that is the busbar is relatively inexpensive while offering proven reliability which has been used for the long period of time. All live contacts in sulfur hexafluoride; that is SF6; experience as shown that air insulated substation.

Disconnectors switch contact requires relatively high level of maintenance, so while experience with the GIS is exactly the opposite. So, this could be reduced in going for gas insulated switchgear. So, the of SF6 or sulfur hexafluoride technology makes the hybrid switchgear virtually maintenance free; very important point to considered, this will combined with the high level of reliability to ensure the lower global life cycle cost going in for hybrid.

And the hybrid substations as fewer switching elements because this uses the gas insulated technology and allows rationalization of the switching elements and also the factory pre-assembled and tested the hybrid modules are fully pre-assembled and tested in the factory and for monitoring an online diagnostics, the use of the electronic monitoring and online remote diagnostic are also available by going in for the hybrid substation. So, several advantages of trying to reduce the cost in comparison to the full gas insulated or a complete metal clads gas insulated substation.

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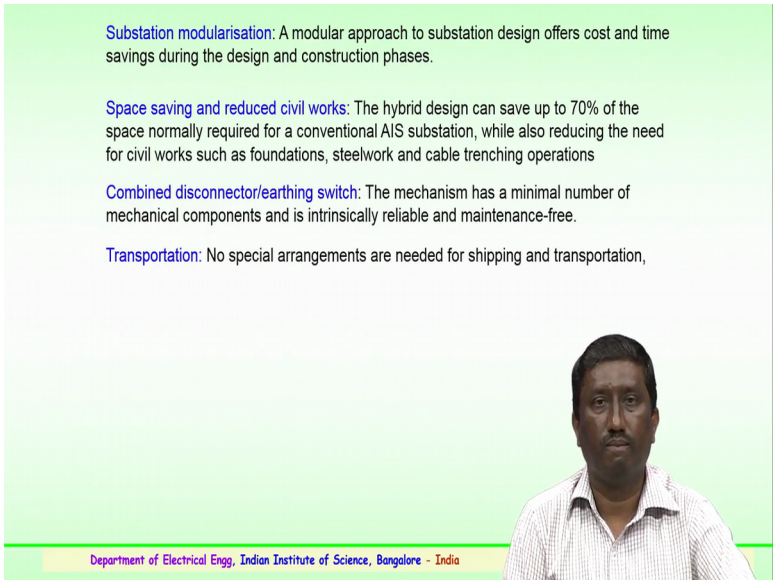

So, substation modularization again a modular approach to the substation design offers cost and time and also savings during the design and construction phase. A phase saving and reduced the civil works, so the hybrid design can save up to 70 present of the space which is required conventional like the air insulated substation. So, going in for hybrid could be reduced by 70 percent of the space and also it reduces the need for civil work; such as a foundations the steelwork and also the cable trenching operation etcetera.

So, on the combined disconnector or earthing switches here again the mechanism has to be a minimal number of mechanical components and is intrinsically more reliable and this will be maintenance free. So, this combined disconnector switch operation could be also very useful, when you go for the hybrid type of substation and in case of transportation there is no special arrangements which are needed for shipping transportation, it is much easier like the air insulated substation.

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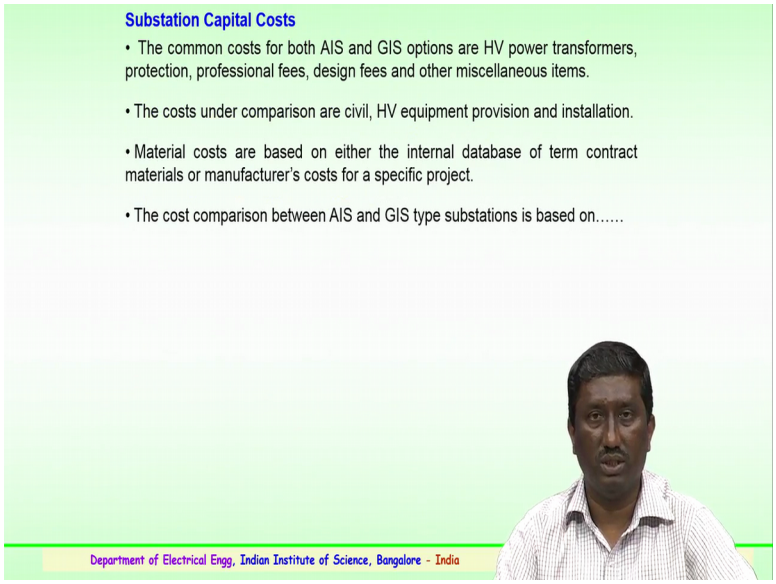

So, substation capital costs or in comparison of this three technologies, so the common costs for both the air insulated and the gas insulated options are mainly the high voltage power transformers very important components. The protection systems this could be several city current transformer, potential transformer, the surge arresters, the isolator switches several relays and the SCADA arrangements, the professional fees, design fees and other miscellaneous items; all this come under the capital cost when the planning is being carried out for the any substation.

These cost under comparison are civil high voltage equipment provision and also installation. The material cost are based on either the internal data base of the term cost contract materials or the manufacture cost for a specific project and a specific voltage level and going in for what type of substation to be adopted. So, the cost comparison between the air insulated, the gas insulated type substations is again a very difficult comparison; this depends on the area where this is to be compared.

So, comparing the air insulated, gas insulated in general maybe of a difficult scenario, it could be compared only where the; in case of the metro or the thickly populated the areas. In such cases where land is of a prime cost, so in such cases the comparison could be made. In case the land availability is at a less economical or less cost; the comparison may not be the correct thing to be done. So, this comparison cannot be directly compared

with the GIS and AIS and it can be done based on the that particular area which is to be carried out.

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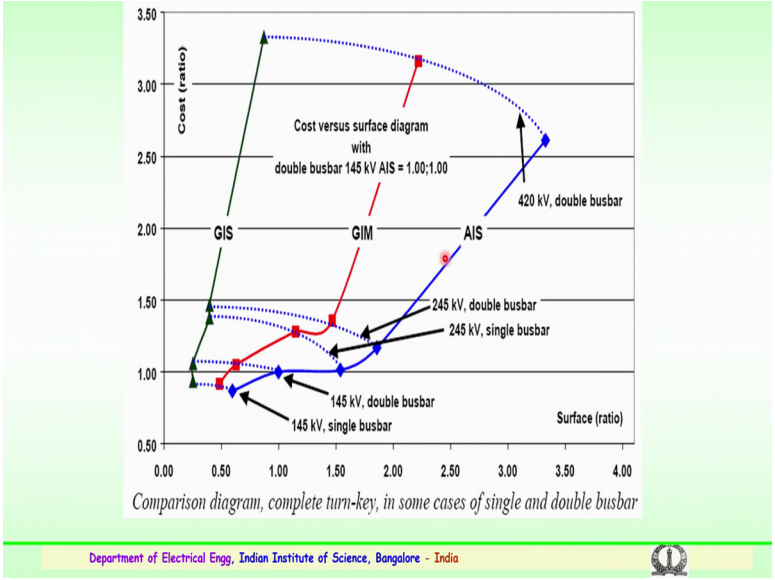

This generally this graph as you can see it shows, a general comparison diagram for three technologies; gas insulated, air insulated and the hybrid insulated or a going in for that hybrid substation. This shows the cost ratio in the Y axis and the surface ratio; for various busbar, the comparison made for 145 to 245 and a 400kV busbar with single and double bus.

You can very clearly see the comparison going in for a complete gas insulated substation and the cost will be definitely high in comparison with the air insulated cost and the surface ratio also is being plotted and going in for the hybrid could be anywhere between the gas insulated and reduction; substation reduction comparison to the gas insulated could be seen after the air insulated. So, again the utilities and the planners have to decide to going for which type of technology has to be adopted either fully gas insulated or the air insulated substation which is to be planned.

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So, apart from this substations; and some of the cases is the requirement could be a mobile type of substation and emergency and some related requirements. So, in such cases few of the countries are also adopted, the mobile substations for the emergency catering, you could not see one typical 245kV substation which is available in Abu Dhabi, where from mobile it could be used in case of the emergency needs. Similarly, for railways in Switzerland; a mobile type of substation is available; these are few examples in case of emergency requirements.