Advances in UHV Transmission and Distribution
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Lecture - 34
Importance of Generation of HVAC, Impulse Voltage and Currents in the laboratory

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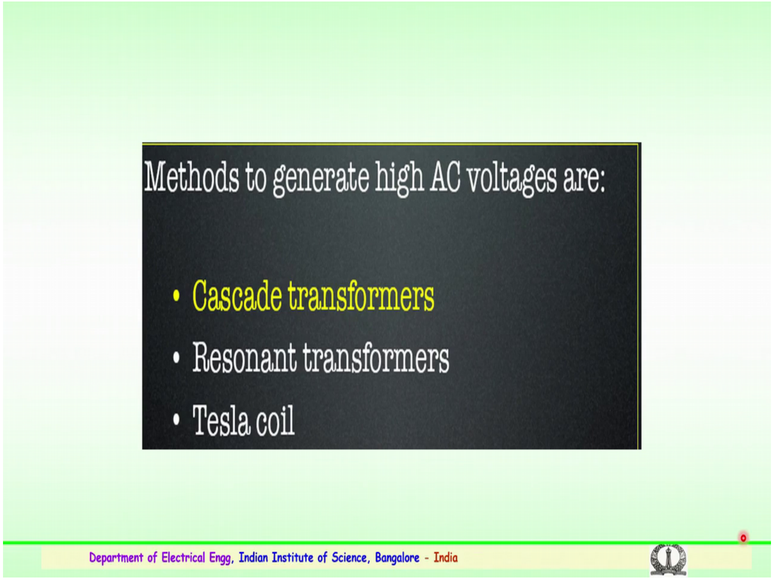

That was about the high voltage DC generation. So, now, various methods are there to generate the high voltage AC. So, the important being the use of a cascade transformers, the second is a resonant transformers and third is the Tesla coil, but for a testing of a high voltage equipments normally the cascade transformers are employed. So, we will briefly discuss about the cascade transformers, which are used for the generation of a high a voltage AC.

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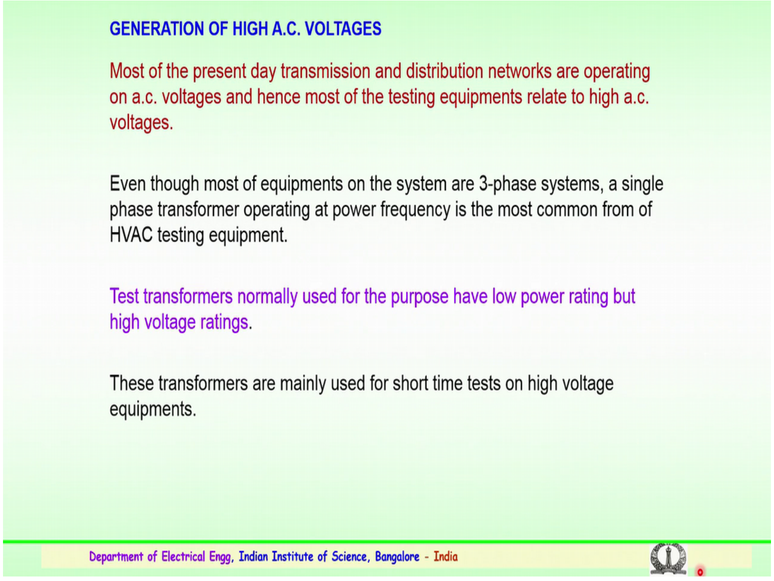

You know that a most of the present day transmission and distribution networks operate on a high AC voltages and hence most of the testing equipments relate to high voltage AC. Even though most of the equipments on the system are 3-phase, a single phase transformer operating at power frequency is the most common method or form of a testing the high voltage equipment using the HVAC. So, the test transformers which are used for the purpose have a very low power rating, but high voltage a ratings. So, current rating will be very less and the power rating will be less, but the voltage rating will be very high which is required for the testing of any high voltage equipment which is used for the transmission or a distribution systems. So, these transformers are mainly used for a very short tests on high voltage equipments. So, these are not for a very long duration. So, the tests are usually conducted for a short time period.

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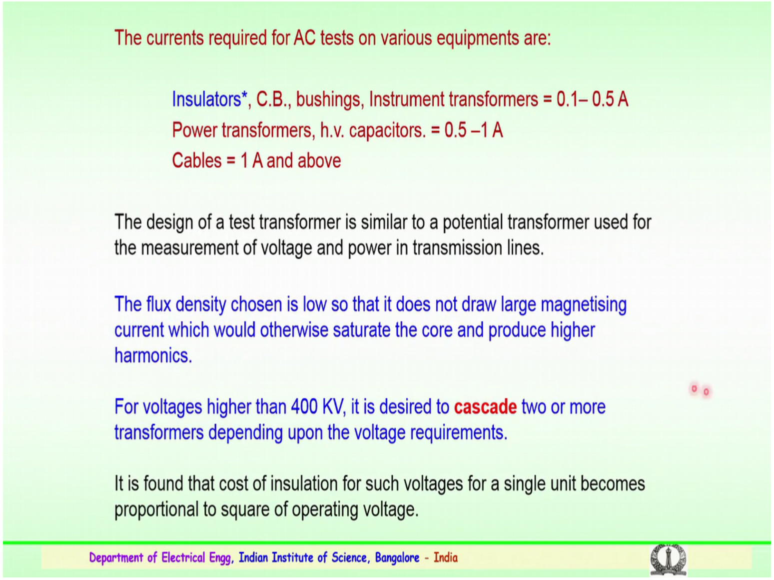

And the currents required for the conduction of a the AC tests vary with various equipments. So, there is a standards for each of the equipments. What is the current to be applied and all the duration to be applied, example insulators could be circuit breakers, bushings and instrument transformers, the specified current ratings is anywhere between 0.1 to 0.5 amps. For power transformers high voltage capacitors the current rating of the AC tests to be done is 0.5 and between 1 amp. For cables it is generally 1 amp and above.

So, the design of a test transformer should be is normally similar to your potential transformer which is used for the measurement of voltage and power in the transmission lines or in the substations. And importance is the flux density chosen is a low, so that it does not draw a large magnetizing current, this would otherwise saturate and the core produce higher harmonics. So, for voltages higher than 400 KV, it is desired and it is recommended to going for cascading the transformers for testing, either a cascading two three or more units depending upon the voltage requirements for the test. It is found that the cost of insulation for very high voltages in case going in for a single unit will become proportional to the square of operating voltage. So, you can see that in case the voltage level 765, 800 KV or above the cost becomes very high for the design of the insulation aspects that is one of the reason going in for the cascade.

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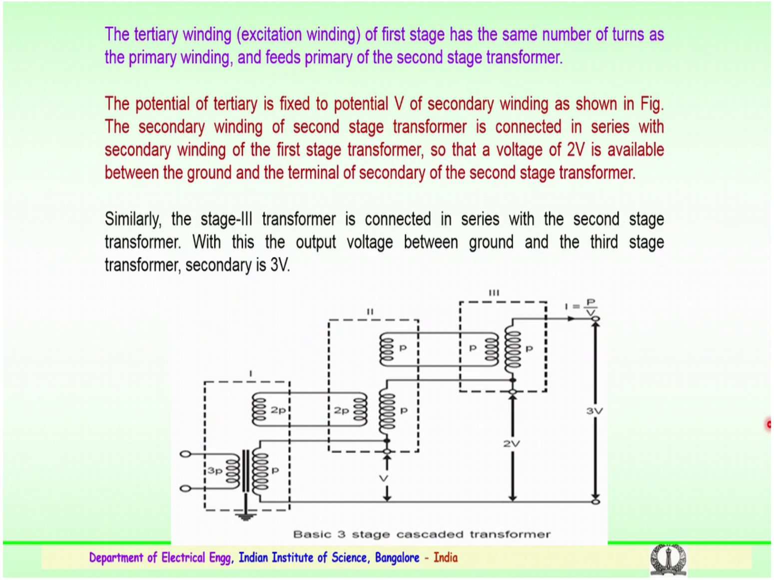

So, basically the cascade connection is shown here. You have a transformer here. The first transformer, which is a shown here. The winding on the first transformer a portion of the winding are exciting winding or a tertiary winding is taken out from the first transformer and this forms the primary of the second transformer. Similarly, the secondary excitation or a tertiary winding on the secondary transformer forms the primary winding of the third transformer. So, this is how the connections are made for different stages, this gives three stage cascaded transformer. We see the potential raise here, the first output will be a potential V here. Once the cascading of the second transformer is done we see a voltage of 2 V at this junction at this point the output point; and in case the three transformers are cascaded, we can see 3 V that is a three times the voltage of the primary. So, this is how the cascading is done.

So, brief explanation about this. So, the tertiary winding or the excitation winding of the first stage this is the tertiary winding of the excitation winding of the first stage has the same number of terns as the primary winding and feeds the primary of the second transformer. So, all the primary windings will be of the same number of turns, and for cascading the important is all the three transformers should be identical in nature that is very important. So, the potential of the tertiary is fixed to potential V here of the secondary winding. The secondary winding of second transformer that is a secondary this transformer is connected in series with the secondary winding of the first stage transformer you can see here, this is connected to the first. So, that the voltage of 2 V -

the output the output voltage of 2 V is available between the ground and the terminal of the second voltage term. So, this is the second stage.

Similarly in case for a stage three is connected in series with the second stage, the excitation winding of the second stage is connected to the primary of the third transformer. And within this the output voltage between the output of the third stage and the ground will see up 3 V. So, third stage transformer the secondary of the third stage will have a 3 V, this is how the cascading of the transformer is done.

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So, various cascading of the transformers two three four units are normally done at various high voltage laboratories depending upon the requirement of the voltage to be used for the testing of the equipments. So, one such example is at the Indian Institute of Science where we have a three units of 350 KV each unit is 350 KV is cascaded. So, we do get the voltage for the three cascaded transformer a voltage of 1050 KV that is a 1050 KV which is 350 KV So, across this a terminal we could get 700 KV and here across the third terminal we get 1050 KV.

So, similarly there are laboratories across the globe depending upon the voltage a requirement a suitable cascading is carried out and necessary output is obtained for the testing of a various equipments. So, here this equipment or the IISC is used for several of the projects in the national level projects which have been conducted earlier for a 400 kilovolts systems, 800 KV transmission systems. And this a transformer was used for conducting a various types of testing like the AC withstand test, the flash over the radio interference test, the corona and other AC tests.

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Similarly, this is an example of a three stage cascade transformer which is kept outside in one of the laboratories having a capability of a 3 into 600 kilovolts that is a 1800 will be the output across the third stage with a current rating of a two amps. This is an outdoor type with a divider suitable divider having 1500 KV divider. So, previously I would like to go here a here again we have a 1050 KV, 1 amp AC source.

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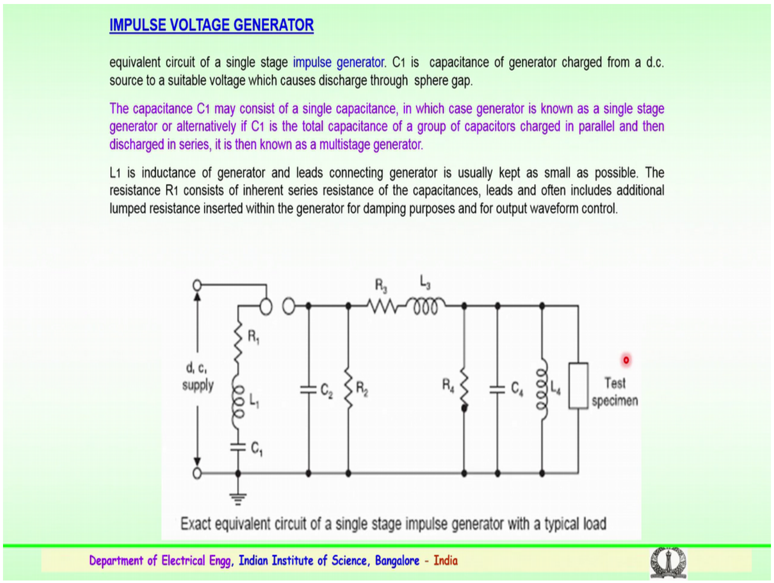

Next we have looked into the important about the generation of DC for the laboratory testing the second was about the AC aspects, how the high a AC voltages are generated which will be used for the testing of the equipment. The third is the impulse a voltage generator or the surge generator very important as this surge generator plays a important role in the generation of the lightning as well as the switching surges which have to be tested for the equipment used in the transmission or the high voltage distribution networks. So, the impulse voltage generator the equivalent circuit or the exact equivalent circuit of a single a stage impulse generator is mentioned here. The input is the DC supply. You have a capacitor a C 1 generator capacitance you have c 2 a capacitance here. Again this is R 1, R 2 or the this load capacitance R 1, R 2 or R 2, R 3 are the wave shaping a resisters. Here we can very clearly see C 1 is the capacitance of the generator which is a charged from a DC supply to a suitable voltage which is required and where this charge which is accumulated in the capacitor will be discharged through the help of this sphere gaps.

So, the capacitance C 1 could also consist of a single capacitance or number of capacitances. For a multistage impulse generator a number of capacitors are connected in parallel and discharged through the series arrangement using a sphere gap. So, group of capacitor or multi capacitors are charged parallel then discharged in series, this we call it as a multistage generator if you more number of capacitors are used. L 1 is the inductance of the generator and the leads which are connecting so usually this lead should be very, very small as possible. And there is r one is shown here it consist of an inherent a series a resistance of the capacitances leads and a often includes additional lumped resistance which is inserted within the generator particularly for a damping purpose. So, generator consists of a damping resisters and also for the output waveform control.

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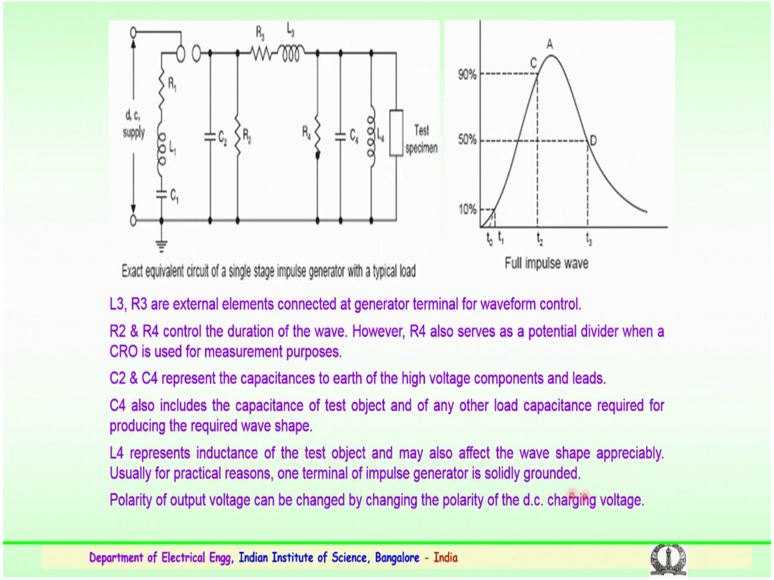

So, L 3 and R 3 are the external elements which are connected at the generator terminals for the waveform control. So, it is a front wave of the waveform example typically if this waveform is of 1.2 by 50. So, the resistance front resistance that is R 3 controls the front and R 4 controls the tail, so that has to be kept in mind. So, L 3 are the external resistances connected in generator terminals for the waveform control R 3. R 2 and R 4, so this R 2 and R 4 control the duration of the wave, so waveform what a whether it is 1.2 by 50 or 250 by 2500, so this control the tail resisters. So, however, the important R 4 serves sometimes as a potential dividers.

So, you can with the help of one more a small a resister you can tap the voltage and it could be used as a potential divider and be connected to a CRO for the measurement purpose where the divider is not available. So, C 2 and C 4, this C 2 and C 4 represent the capacitance of the earth of the high voltage equipment or a component and the leads. Particularly C 4 also includes the capacitance of the test object and of any other load a capacitance required for producing the required. So, for the wave shape, so this play a role R 3 C 4 R 4 play a role in the waveform shaping.

So, L 4 is represents the inductance of the test object and may also effect the wave shape appreciably usually for a practical a reasons one terminal of the impulse generator is solidly grounded, here you can see once has to be solidly grounded. So, the polarity of output voltage either can be changed by changing the polarity of DC supply here positive and negative, you can change the supply. And you can obtain the required polarity either positive polarity or a negative polarity.

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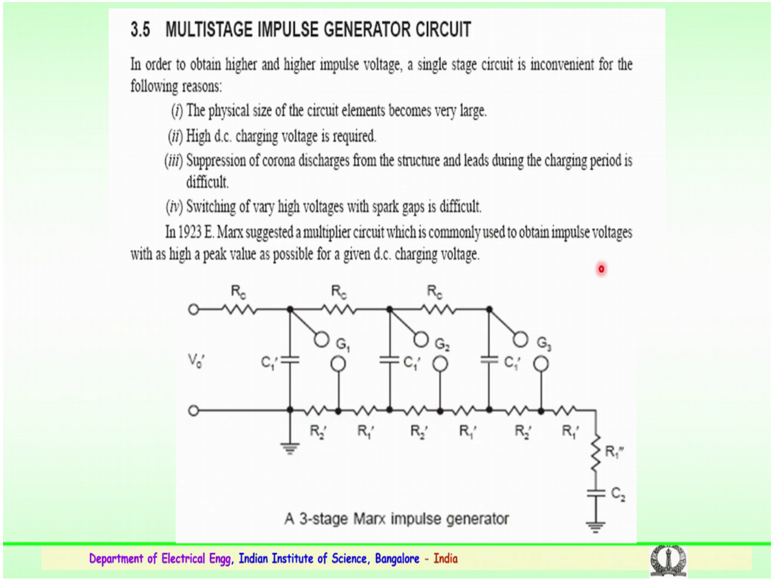

So, similar to the multiple stage DC here the multiple stage a impulse generator is the being shown here. This is based on the Marx principle to obtain the higher and higher voltage levels, where earlier a single circuit or a single stage circuit was inconvenient for the reasons because the physical size of circuit elements becomes very large if you are going. And high DC charging the voltage also is required in case if you use only one stage and later the separation of corona discharges from the structure and leads particularly during the charging period is very, very difficult.

So, switching of a very high voltages with a spark gaps also is equally difficult in case if it is a single stage a impulse generator. So, in 1923 Marx suggested a multiplier circuit which is commonly used to obtain an impulse voltages with a very high peak value as possible for a DC charging a voltage. So, this is again the charging resisters where you see for each stage a spark gaps for each stage and the capacitances of the generator number of stages. So, here the voltage is applied a DC voltage and all the capacitors are charged in parallel after the charging in parallel a suitable mechanism is made where the entire charge is discharged through the sphere gap arrangement and it flows in this way. And you get the output voltage depending upon the number of stages. So, this is a simple mechanism which is being followed for the development of generation of very high DC voltages and which is used for the measurement of the an application of the very large voltages. Again R 1 and R 1 dash are helpful for the waveform requirements similarly C 2.

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This is one of the modular unit at the laboratory which we have is the 400 KV impulse generator consisting of a AC unit of 100 kilo volts and output with the DC is 140, and a 420 KV impulse generator with the divider arrangement.

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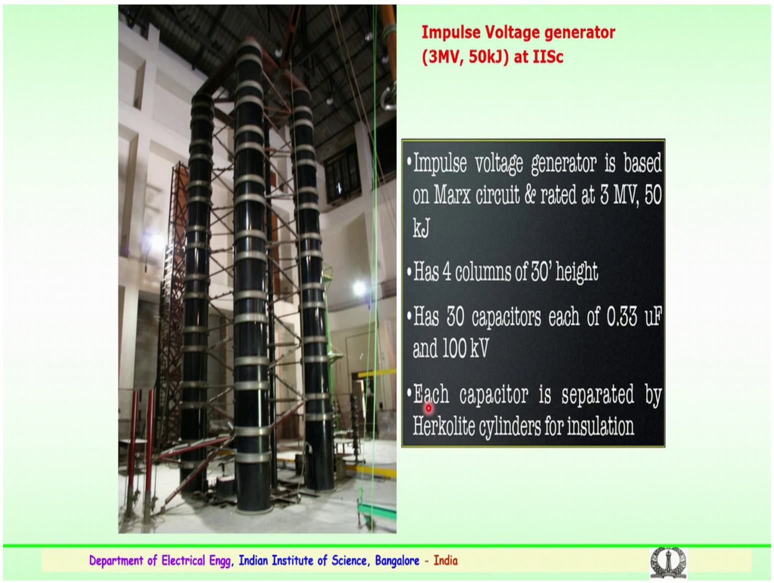

And important is we have an impulse voltage generator which is of 3 million volt, 50 kilojoules available. This simple generator is mainly based on the Marx principle which has been described and rated for 3 million volts where both a lightning and a switching surges could be generated, this generator at IISC has a four column having capacitors with 15 stages. So, it has a four column a 15 stages, each stage output is 200 kilowatt. So, each stage is 200, so 15 stages into 200 is 3 million volt is a lightening impulse. And for switching impulse again suitable RS and a RD that is the front resisters tail resistor and the capacitor is being used for suitable waveform requirement and could be achieved.

So, we have a 30 capacitors or 15 stages two capacitors each stage with a rating of 0.33 microfarad operating at 100 kilovolts, and this capacitors you can see that between these two aluminium rings, the capacitor is housed inside with the help of a herkolite insulating chamber. So, the black chamber herkolite chamber is an insulating media. So, capacitors are housed in between the two a rings. So, two capacitor at each block, so 15 stages, you have 200 KV per stage. So, 3 k million is the output voltage which is being used to test for the lightning and switching surges for the high voltage transmission equipments circuit breakers, transformers, insulator strings many, many equipment which are used for EHV and UHV transmission.

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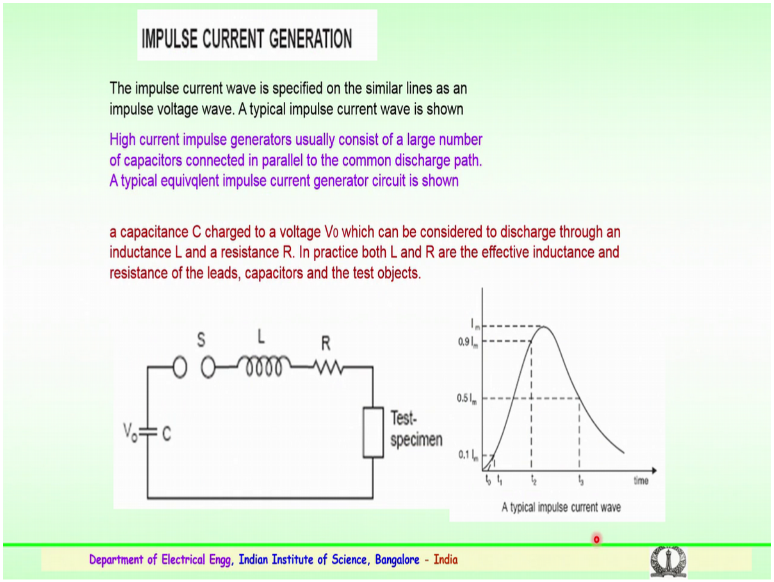

Next is the impulse current generation. So, during the lightning activity in the atmosphere when the equipment its tagged with the lightning activity both the impulse voltage and impulse current are observed and this impulse current is also very important and impulse current generation also is important in the laboratories for the testing of the equipments. So, the impulse current wave is normally specified on the similar lines as a impulse voltage wave, a typically which was specified could be in lightening impulse voltages 1.2 by 50 or 250 by 2500 for switching surges. Here typically impulse current wave could be 8 by 20 microseconds, 8 be the front time and 20 be the tail time.

So, 8 by 20 is typically a lightening a impulse current wave and there are other waveforms like the high current which is a 4 by 10, and there are sharp rise waveforms which are 1 by 20 and so on used for a the testing of a various equipment in the high voltage laboratories. So, the high current impulse generators usually consists of a large a number of a capacitors again here similar to the impulse a voltage generator. But here the connected in parallel like earlier for impulse voltage also capacitor are connected in parallel. Number of a capacitors are connected in parallel and discharged in series with the sphere gap in case of impulse voltage. Here the capacitors are connected in parallel to a common discharge path and are all discharged in parallel then you get a very high impulse a currents.

So, the typical equivalent impulse current a circuit is a shown here, this is a number of capacitors in parallel. So, this number of capacitors in parallel are discharged in parallel through a sphere gap a mechanism and L and R being the waveform requirements for the waveform the suitable requirement for the waveform, and the test specimen is connected for the testing of a particular specimen is connected here. So, a capacitance C could be a number of a capacitors in parallel charge through a voltage V naught can be considered to discharge through an inductor and a register in practice both L and R are effective inductance and resistance of the leads also the capacitors and the test object. So, this is how you get a very high impulse current waveform typical shape is 8 by 20.

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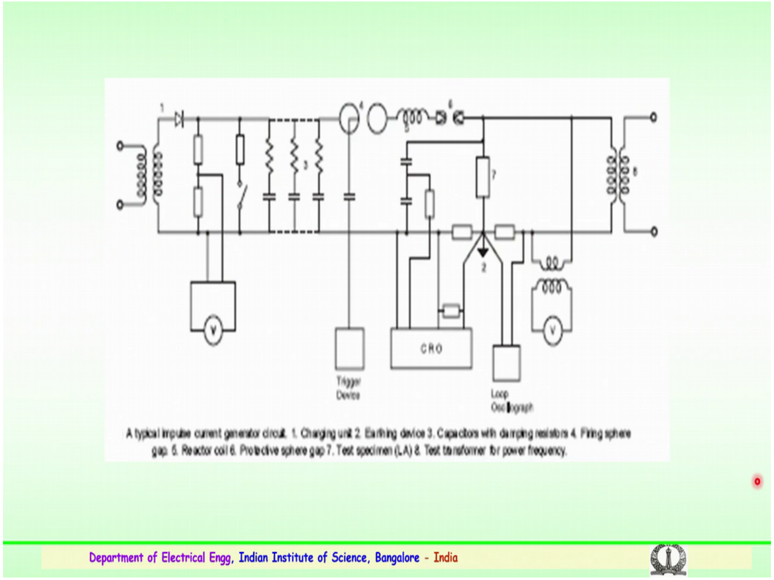

So, this is again one of the typical impulse current generator which is being shown where a testing of our an equipment example a lightning arrestor is conducted and involving both the field conditions similar to a field conditions where we have an AC transformer and also the impulse current generator here. So, this is a typical circuit which is used to test the equipment the equipment could be the lightning arrestor here. So, that lightning arrestor is continuously supplied with the AC voltage and a suitable impulse current generator is here. And impulse currents of a values are discharged by number of capacitors which are in parallel through the sphere gap mechanism and super imposing on the AC waveform and measurements are being conducted. So, this is a typical example of the surge arrestor or a lightning arrestor activity testing in the laboratory for both the AC and the impulse DC or the impulse currents.

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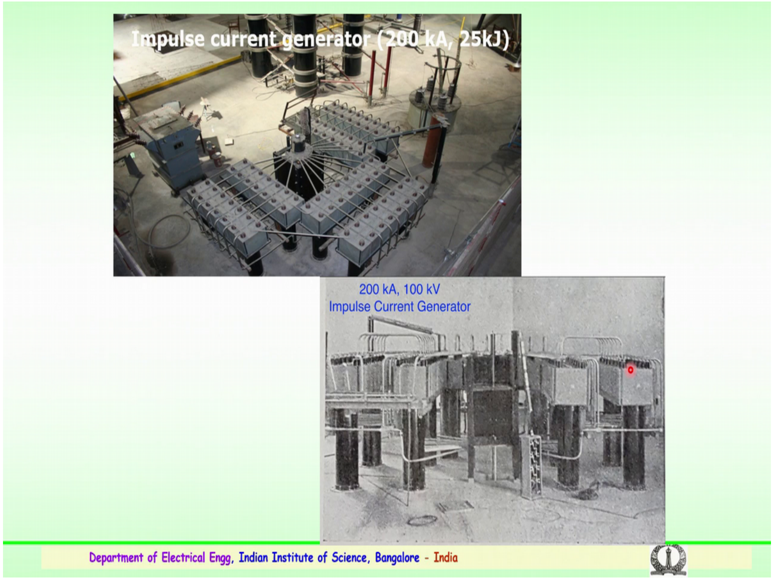

So, this shows the number of capacitors rating which is available at the laboratory we have U type of arrangements to reduce the inductance basically into generator very high currents. So, you have 48 capacitors which are kept in parallel and all this capacitors are discharged in parallel through a gap 3 electrode gap mechanism which is somewhere here and the test object is placed here. So, the entire charge which has a been from this capacitors will be charge discharged parallely through the sphere gap mechanism by a triggering activity. And this entire charge will be flowing through the test object and measurements could be done. So, this is again impulse current generator with a different view which is available in the laboratory rating of 200 kiloamps with a 25 kilo joules. Very important for the testing of lightning currents for sized arrestors lightning arrestors calibration of a rogues key quartz and many, many more works.

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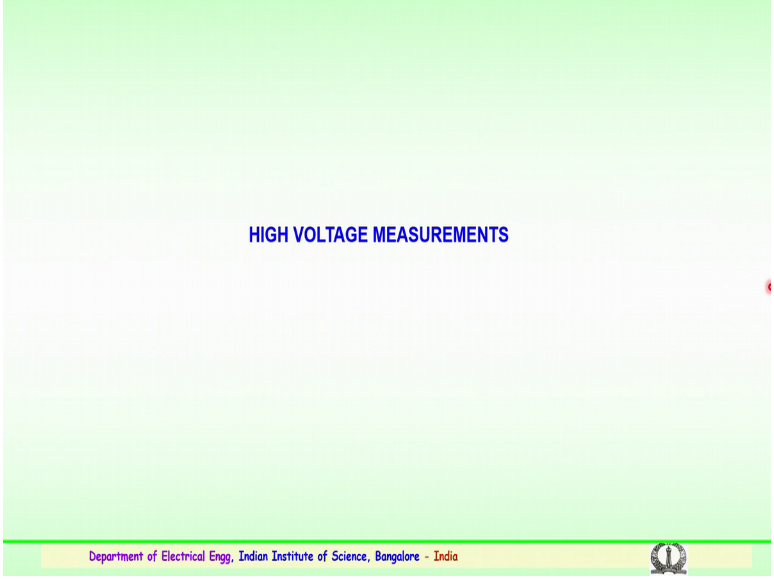

So, that is about the generation of the AC and the generation of the DC and generation of a high impulse a surges voltage surges both for lightning and switching aspects and also the generation of high impulse currents. So, this was about the basic information which is essential for any laboratories before the equipments are being tested. And these equipments which are used in high transmission at a very high voltages or ultra high voltages have to be initially tested as per the specifications laid out by the international standard organizations. And suitable testing will give an information for such aspects the laboratory should be equipped with the high voltage a DC, the high voltage AC the surge a generators both a voltage and currents.

So, thank you.