DC Power Transmission Systems
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Lecture - 07
Choice of converter configuration: Transformer utilization factor

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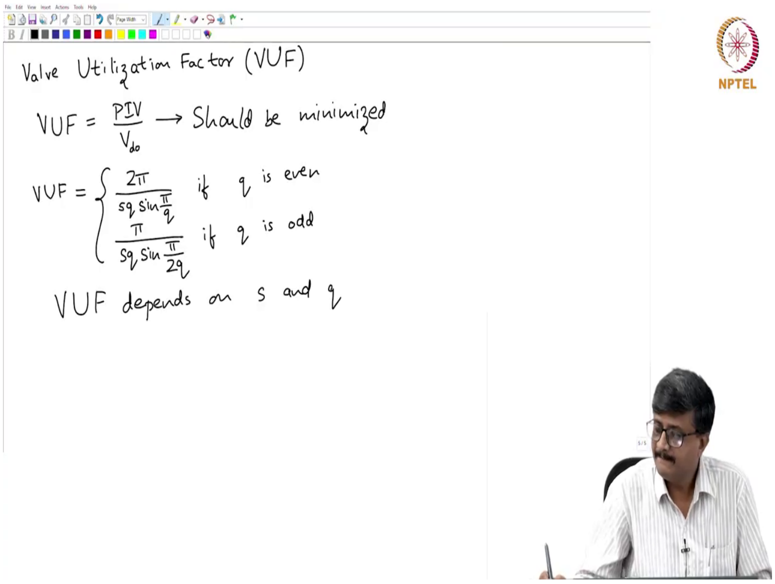

So, let us move on to the next figure of merit.

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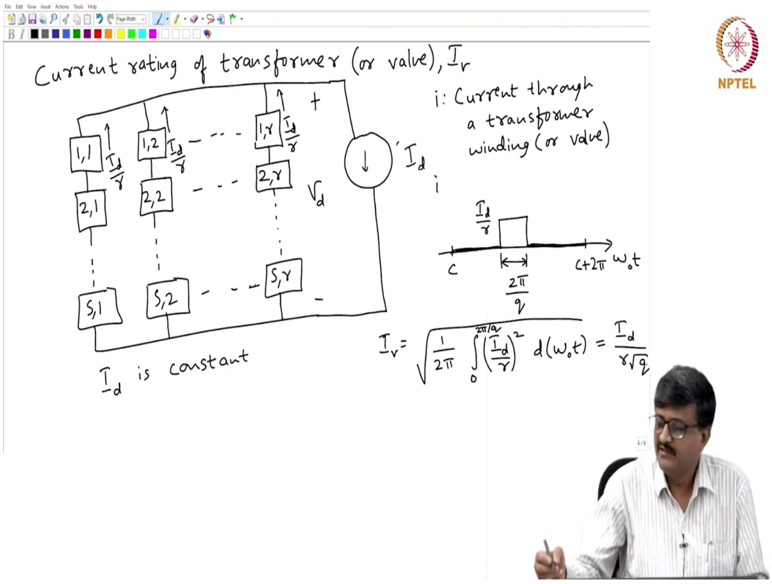

So, the next before going to the actual figure of merit, what I will do is I will we need some quantities here that is current rating of transformer. Now, since the any transformer winding is dependent on the current that flows the RMS value. So, we are essentially trying to find the RMS value.

Now, you would noted that any transformer winding is are connected in series with thyristor valve. So, current rating of a transformer or a valve are one of the same. So, take any one transformer winding. What is the current rating of the transformer winding or valve? They are connected in series. So, the same current flows.

So, for that we will just go back to the circuit see the circuit is like this I have 1 comma 1 many commutation groups connected in series 2 comma 1 and so on. S comma 1 1 comma 2, 2 comma 2 and so on up to S comma 2. So, we have many such parallel paths. 1 comma r connected in series with 2 comma r and so on connected in series with S comma r and all these parallel paths have two terminals, they are brought out.

So, the voltage which appears here is V d, the instantaneous voltage. Now, I make one assumption here. On the DC side, I assume that there is a say large filter, current filter say an inductor can acts actually act as a current filter. So, due to which for the sake of simplicity, I can represent the DC side current as a constant current I d. So, I d is constant that is an assumption and it is justified if I use a current filter for example, an inductor on the DC side.

So, with this assumption of a constant current on the DC side, if I want the current rating of a transformer. So, how do I get the current rating of a transformer? So, any transformer winding. So, current rating of any transformer winding or any valve connected in series with the transformer winding. So, for that I have to look at the current in the individual parallel paths.

Student: (Refer Time: 03:23).

If you look at any parallel path in any of these, what is the current?

Student: (Refer Time: 03:32).

I d by r; I d by r by symmetry all the currents are equal ok. Now, the question is the same I d by r flows through if I take any parallel path or same I d by r flows through all the commutation groups, there are S number of commutation groups in any parallel path. Now, in each commutation groups, there are q paths. Now, what is the current in each of these paths, that is the current I am looking at.

So, I want the current rating of a transformer winding is which is in each of these q paths. So, what is the shape of the current? Suppose, i is the instantaneous current through a transformer winding or a valve of course, because they are connected in series ok. So, it is a instantaneous current.

So, how is this wave form of i as a function of omega o t; so I want the wave form of i as the function of omega o t. Say I know that the current through the basic commutation group is constant I d by r. Since I d is constant I d by r is also constant. But what is the current through any one transformer winding or any one valve?

Student: (Refer Time: 05:08).

If I or you are saying i is constant. Now, go back to the working of the basic commutation group at any instant only.

Student: 1 (Refer Time: 05:22).

One transformer winding or one valve is conducting and all the transformers and all the valves get a chance to conduct.

Student: (Refer Time: 05:31).

Are you saying all will conduct all the time?

Student: (Refer Time: 05:36).

At any instant only one conducts and all will conduct all will get a chance to conduct. So, that will rule out the possibility of constant i.

Student: (Refer Time: 05:46).

If only one conducts, then for that particular transformer winding its constant which is nonzero and for others it is 0.

Student: Yes.

No, that should not happen. At any instant one conducts and all will get an equal opportunity to conduct.

Student: (Refer Time: 06:03).

So, what is a wave form?

Student: (Refer Time: 06:06).

It is a pulse. So, it is a nonzero value. If I take say any cycle of the AC side voltage, suppose I can find a c any arbitraries, some c and c plus 2 pi this is one cycle. I can always find a c such that between these 2 instants, there is a wave form for i which is like a pulse of value. So, it is 0 everywhere except for a certain duration at which it is. So, there is a certain duration for which it is nonzero; otherwise it is 0. So, this is 0; this is 0. So, it is nonzero for a certain duration and it is nonzero means what is the value?

Student: I d by r.

I d by r. See this I d by r which is shown in any parallel path will flow through the basic commutation group. If you take any individual path in the basic commutation group, the current is still I d by r because only one thyristor conducts at any time; only one thyristor all conducts. But what is the duration for which the current is nonzero?

Student: 2 pi by q.

2 pi by q. So, there are q such parallel paths. So, it is 2 pi by q. So, this is the wave form of the current through any transformer or any valve. Now, the question is if I want current rating, how to get current rating from this? I just mentioned that current rate by current rating what do you mean?

Student: RMS value.

Rms value. So, you have to get the RMS values. So, the we denote the current rating of transformer or a valve by the notation I v; v for valve, v for valve ok. So, lets the RMS value of the current through the transformer winding or valve. So, I v is RMS value; root mean square value. So, I have to take the square root of the mean.

So, there is a period 2 pi and I have to take the average of the arithmetic mean of the square of the current. So, it is I d by r square d omega t and I have to just integrate this between any 2 limits which differ by 2 pi by q. So, say 0 to 2 pi by q ok. So, that is all I have to do to get the RMS. So, this gives the RMS value as I d by r root q.

So, this is the current rating of the transformer or valve now, but I mean I just wrote valve in bracket just to mean that valve rating the valve current rating and transformer current rating are same. But what we are interested now is in the rating of the transformer. So, when you just say rating what I mean is the volt ampere rating of the transformer.

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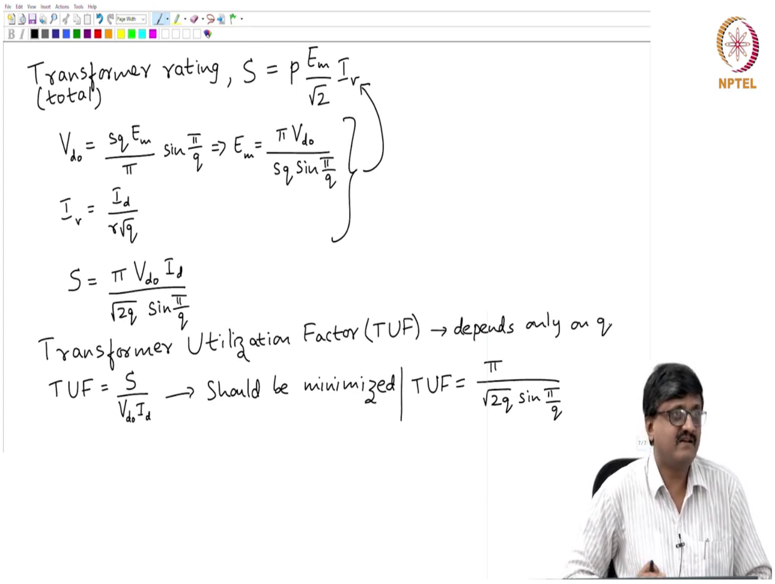

So, using this current rating we will come to what is known as the volt ampere rating of the transformer. So, it is simply called transformer rating. So, what I mean here is the total transformer rating; say how many transformers windings are there? How many transformer windings are there? In each commutation group you have q; that means, multiplied by S that is multiplied by r. So, it is q into r into S so many transformer windings we have.

So, what is the total transformer rating? See when I said transformer rating or I mean the total transformer rating. So, let me give a notation for this S. S is the usual symbol which is used for volt ampere this is the apparent power ok. So, what is this transformer rating and how is it defined? How do you define the transformer rating?

Student: (Refer Time: 10:25).

Sorry?

Student: (Refer Time: 10:27).

It is the product of RMS voltage and RMS current ok. So, I take the total transformer rating. So, I said it is q into r into S which is nothing but the pulse number p; q into r into S is p. Then, I mean the lower case p stands for q into r into S. So, p is the total number of transformer windings.

And the rating of each transformer winding is the RMS voltage into RMS current. What is the RMS voltage? In terms of notations that we have already used, say we have use the notation E m. So, can I get RMS value in terms of E m? So, it is sinusoidal; please note voltage is sinusoidal that the AC voltage is sinusoidal. So, the RMS value is E m by root 2 into the RMS current, just now we gave a notation for this I v. So, we you can just substitute the expression for I v.

Now, what will do here is we will also try to get this expression for E m in terms of V d o say just recall we derived an expression for V d o. What is V d o? V d o is S q E m by pi sin pi by q V d o is the maximum average DC voltage. So, we will try to substitute the expression for E m using this equation. So, this gives E m is equal to pi V d o divided by S q sin pi by q and we just now derived the expression for I v. I d by r root q.

So, substitute the expression for E m and the expression for I v in the expression for S. So, that gives the expression for S as after simplification. So, we will not get the expression in terms of E m anymore, we will get it in terms of V d o of course. So, it is pi V d o I d divided by. So, I can just verify it is easy to verify that it is equal to pi V d o I d divided by under root 2 q sin pi by q. Of course, I used the equation p equal to q r S that is why p is not coming here. So, the p is replaced by q r S and there will be some cancellation.

So, this is the expression that I get for S pi V d o I d by under root 2 q sin pi by q, it is easy to verify you can do that ok. Now, using this we define one more figure of merit see already defined one figure of merit valve utilization factor. The other figure of merit is Transformer Utilization Factor. So, this is abbreviated as TUF. So, the definition is like this. So, the definition of TUF is the ratio of S to V d o I d. Now, we just now what is S? S is the transformer rating. What is V d o I d, I mean? Why I have taken the product V d o I d; product of V d o I d?

Student: (Refer Time: 14:16).

It is the power of the maximum power of the converter, say if I d is constant V d o corresponds to the maximum average DC voltage. So, the maximum power of the converter is coming in the denominator V d o I d. Now, for a given maximum power should I mean what is desirable to have as low value S as possible or as high value of S as possible?

Student: (Refer Time: 14:38).

As low I mean I want to see that I invest as low as possible on the transformer. So, this should be maximized or minimized?

Student: Minimized.

Minimized. Again there is a I mean possible confusion here because when I say transformer utilization should be maximized the utilization factor itself is so, defined that it should be minimized. I mean that I mean one could have avoided this confusion by taking the reciprocal of this instead of taking S by V d o I d. I could have taken the other way. But I do not want to deviate from what is given in the standard references. So, I am just following what is already done by others ok. So, because otherwise when you read you may get a confusion.

So, there are 2 figures of merit which need to be considered. If you look at this figure of merit it depends only on, it depends only on what? I mean I did not do the substitution; can you do the substitution and quickly say what is the expression for TUF so?

Student: (Refer Time: 15:46).

You can just substitute for S, see S is in terms of V d o. So, that V d o gets cancelled with the V d o in the denominator and I d gets cancel. So, it is just pi by under root 2 q sin pi by q. So, it is see you see that it depends only on q ok. So, we will use these 2 factors valve utilization factor and transformer utilization factor to arrive at suitable set of values for q r and S for a given value of p ok.

So, we will continue this in the next class, I will stop here.