Electrical Machines
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Lecture 10
PU Notation and Introduction to Instrument Transformers

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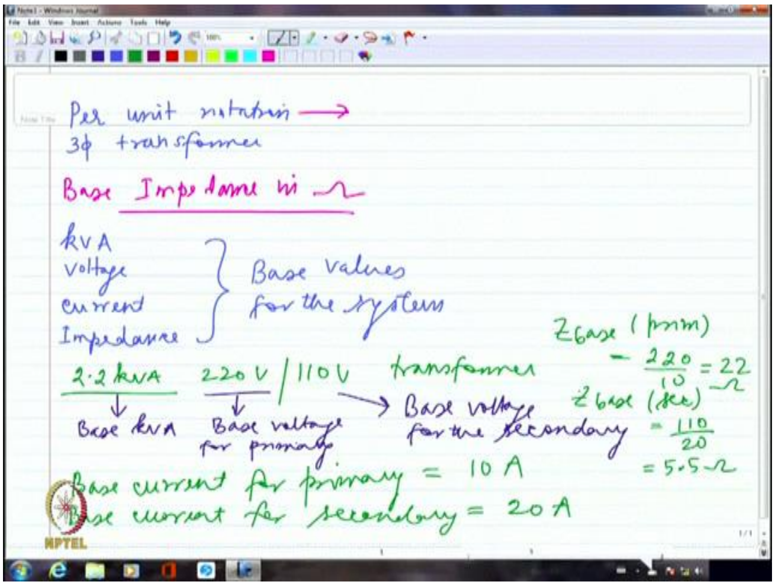

Now let us go over to per unit notation, so in per unit notation we are defining some base impedance in ohms for a particular system and then we are going to say the present value of impedance that I am having for my transformer, primary transformer, secondary which is how much percentage of that is a fraction of the actual impedance of the winding as compared to the base impedance that I am defining.

First of all we should have some way of defining base impedance, so if I am going to take a general power system, I have to fix four values, one is the kVA rating, what is the voltage rating, if I fix these two, automatically current is fixed and impedance will also be fixed. So, I have basically four base values for the system, so if I have a system with a particular value of kVA defined as its base and particular value of voltage define as its base, I can say $\frac{\text{kVA}}{\text{Voltage(kV)}}$ will give me ampere directly.

So that ampere will be base ampere and then whatever is my $\frac{\text{BaseVoltage}}{\text{Ba sec urrent}}$ that I have defined, that will become Z_{base}. Let us take again, for example, what we had taken earlier also, that is 2.2 kVA, $220/110\text{V}$ transformer, so when I have a transformer, generally we will define the kVA as the base kVA for both primary and secondary because the power is invariant in the transformer, whether I am looking at it from the primary side or secondary side, I am going to have the kVA as a constant basically.

So base kVA is 2.2 kVA itself, this is going to be base kVA, whereas this is going to be the base voltage for the primary, whereas this will be the base voltage for the secondary, normally what we do is for a transformer, we will not define a single base voltage, we will define the base voltage for the primary separately, for the secondary separately because we are going to step up or step down, kVA is the same, whereas this is going to be defined independently for each of the sides.

So if I look at the current I will have the base current for the primary, I will have it to be $\frac{2200}{220}$, so that is going to be 10 A, whereas if I look at the base current for the secondary that is going to be 20 A. Now if I define Z_{base}, very clearly for the primary and secondary they would be different. So, Z_{base} if I try to look at it for primary will be $\frac{220}{10} = 22\Omega$, whereas if I try to define Z_{base} for the secondary that would be $\frac{110}{20} = 5.5\Omega$.

So, the base impedance will be different for the primary side and secondary side, similarly base voltages and base currents will be different for the primary side and secondary side, whereas if I look at the kVA, it will be common for all of them. Now what is the real point of defining per unit. So, let us try to look at the utility of it. So, let me take the same transformer.

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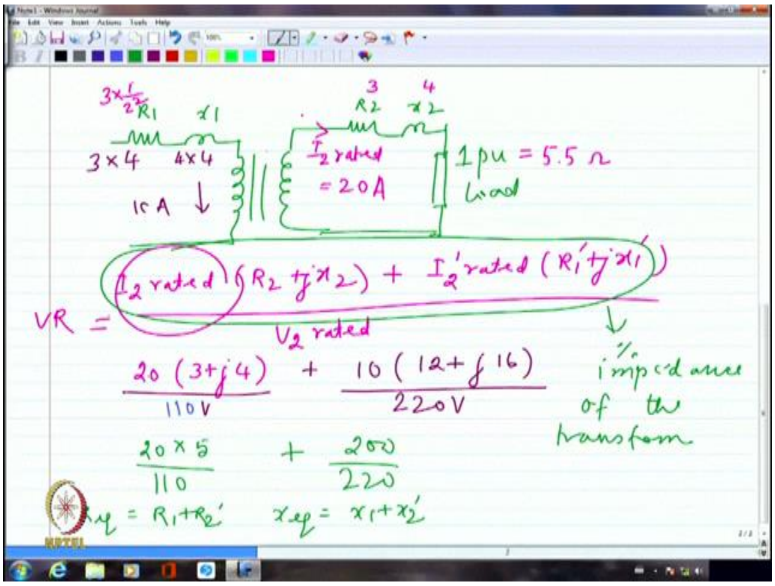

So I am defining here R_1, X_1 and this is my primary, I am not unduly worried about R_C and X_M because I am going to talk more about voltage regulation and maybe more about I^2R, so that is the reason why I am looking at mainly the series parameters. So, I am having this and on the secondary side, I am going to have R_2, X_2, and here is my load.

Now if I am connecting a load of 5.5 Ω, what we calculated as the base impedance under normal operating condition, I should see that the current that is flowing is 100% or rated current. So if I am connecting 1 p.u of load , what I mean by 1 p.u is, same as that of the base impedance that I have calculated, that means that will correspond to 5.5 Ω, if I am connecting this, the current flowing here will be I_2 rated and I_2 rated is same as 20 A.

Whereas this 20 A get translated into the primary side as 10 A and that is also I_{base}. So whether I am looking at both of them, from the primary side or both of them, from the secondary side, from either side I would be able to say as long as I am drawing 100 percent kVA from the transformer, the current that is flowing is 1 p.u, either I watch it from the primary side or the secondary side, so there is no question of transforming from one side to another.

So many times, if you look at the actual values that are given from the industry, they will always give the impedances in terms of per unit and also if I try to see that, $V_R = I_2\text{rated}(R_2 + jX_2) + I_2^{'}\text{rated}(R_1^{'} + jX_1^{'})$ this is the total drop I am going to get in the series parameters of the transformer together. Now this divided by, if I am looking at the whole thing from the secondary side, I will say this is V_2 rated, this is what is regulation, for me this is what is regulation.

So I can call this as voltage regulation, so the voltage regulation is essentially defined like this and what I am looking at basically is the current actually that is being taken from the secondary side directly multiplied by the secondary impedances and current that is translated into the primary side I have to write ofcourse $(R_1 + jX_1)$ I have to translate everything to the secondary side now, because I am talking about everything from the secondary side viewpoint. Rather than this if I had defined everything in terms of per unit, the per unit basically define everything with respect to its own base, it doesn't really change it in any other way.

So, if it is talking about its own base, whether I am talking about I_{1rated} or I_{2rated} as the rated value it will be 1 p.u, it will be 100 percent. So, I am going to write that as 1 p.u, it does not matter. The same way whether I am looking at $R_1^{'} + jX_1^{'}$ with respect to the base impedance of the secondary side or if I talk about $R_1 + jX_1$ with reference to the base impedance of the primary side, it will essentially give me the same kind of drop because I am looking at this current also being referred to the same side, from which I am calculating the impedance.

Let us again take it this way that we are having 20 A here, so I have to write this 20 multiplied by let me just take arbitrarily some value, maybe this is 3 and this is 4, I am simply taking some large value it is does not matter and if I say this is $20(3+j4)$, that is what is the drop, it is very high, but this is the drop that I am getting probably on the secondary side and I told you that generally R_1 and $R_2^{'}$ will be comparable to each other, X_1 and $X_2^{'}$ will be comparable to each other.

So, if I am talking about a similar value coming on the primary side, I have to write this as $3(\frac{1}{2})^2$ Or multiplied by $(2)^2$, I am sorry, not $(\frac{1}{2})^2$, I have to tell you. So, this will be actually 3×4 because $(2)^2$, Because please understand this is $220/110$ V transformer, so if I am saying that both the resistance are comparable, I should have the same 3 Ω on the other side, but refer to the primary side.

So, it will be 3×4 and this will be 3, this will be 4×4 and what will be the current here, current will be only 10 A. So, I have to write this as $10(12+j16)$. So, if I try to look at the voltage drops, this is this voltage drop is with reference to 110 V, whereas this voltage drop will be with reference to 220 V, because one I am looking at it from the primary point of view completely.

So, I have to take its own base voltage, its own base current, its own base impedance and if I am looking at the other one from the secondary viewpoint, I have to take its own current, its own base voltage and its own impedance that is what I have taken. So now if I am actually looking at whatever is the fraction I am getting, you try to calculate what is the percentage, this will be $\frac{20\times 5}{110}$, whereas this will $\sqrt{12^2+16^2}$ =20. So, this will also be $\frac{200}{220}$.

So, both of them are essentially the same amount of percentage that I am getting with reference to its own base voltage. So, when I expressed the impedances in terms of percentages or per unit, it really does not matter whether I am expressing everything from the primary side, everything from the secondary side, partially I am expressing something from the primary side, partially I am expressing something from the secondary side. Overall when I calculated with reference to its own base, I will get ultimately the voltage drops to be at the same percentage values.

So, this entire thing, what I get as the overall voltage drop with respect to the voltage rated, this is generally known as the percentage impedance of the transformer. So, if I am having, let us say $R_{eq}=R_1+R_2^{'}$ and $X_{eq}=X_1+X_2^{'}$,

Student: Are the primary and secondary impedances always comparable?

Professor: See normally in most of the transformers, the primary and secondary will be comparable, you might been having given different values, even if you are given different ohmic values, if you try to convert that into, you know its own base, you will see that the percentage values are comparable, that is one may have 3 percent, the other might be 3.25 or 3.5 percent. That is all I am trying to say, see originally if you had measured the values in this $\frac{220}{110}$ V transformer,

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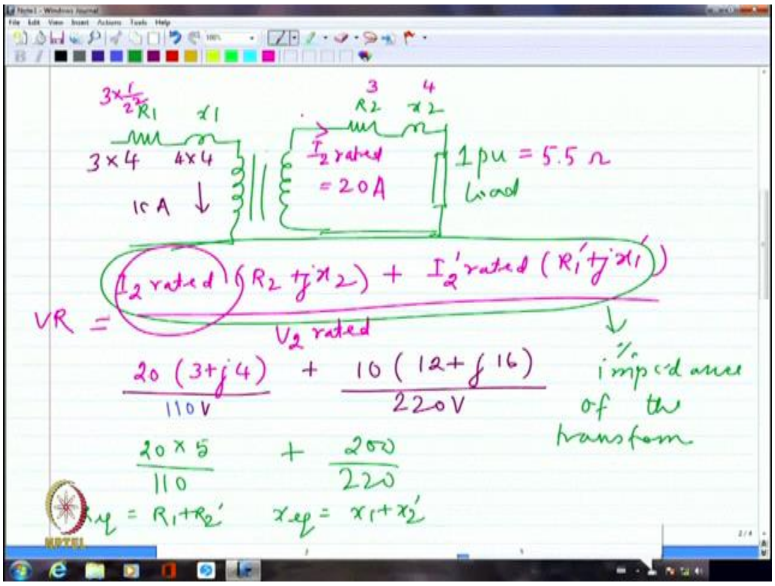

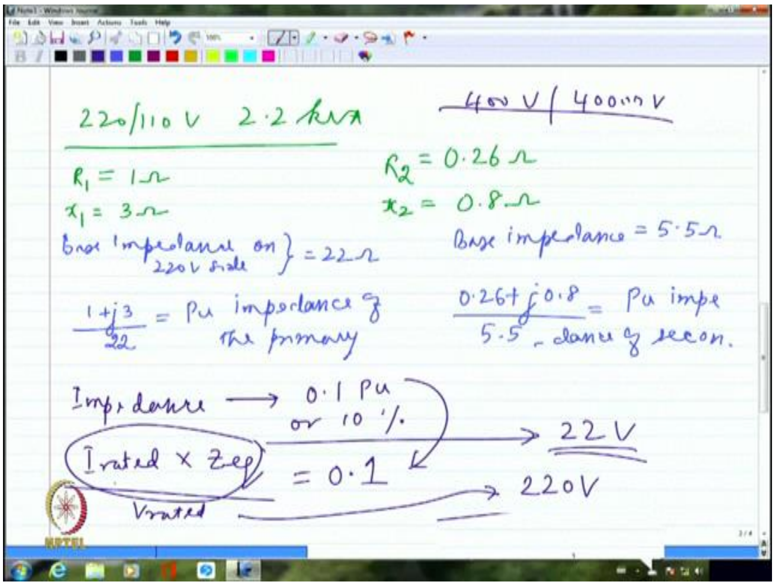

I might have had maybe R_1, do you have that problem that we worked out, can you please give me those values, some arbitrary values I gave, last time we worked out on problem, the same $\frac{220}{110}$ V, open circuited and short-circuit data.

Student: (()) (15:47)

Professor: I can assume it is 5.5 Ω, so it is resistance load, if I have assumed 5.5 Ω simply as a resistance, then I can assume it is in phase, it does not matter, $I_2\angle 0$. So, I am basically talking about the overall impedances 5.5 Ω here, because I am not taken any phase angle, I can assume that it is the resistible as simple as that, if it is not resistive definitely you should having included the phase angle.

So what I am trying to say here is, if it is $220V / 2.2kVA$ transformer, maybe let me say R_1 is 1 Ω, whereas R_2 what I got it should be $\frac{1}{4}$, if it is has to be equal, it can be probably instead of 0.25, it can be 0.26 Ω. similarly I am taking X_1 probably is say 3 Ω, here I should have had X_2 to be probably $\frac{3}{4}$=0.75, but rather than that, let me take this to be 0.8, it does not matter.

Student: (()) (17:12)

Professor: $(\frac{N_1}{N_2})^2$, not, not yes, that is why $\frac{1}{4}$.

Student: (()) (17:28)

Professor: $\frac{220}{110}$, it is the turn's ratio, if I am transferring everything to the primary side, I have to multiply by 4 because 2^2, $(\frac{2}{1})^2$, always remember if I am transferring from high-voltage side to low-voltage side, then it will be $(\frac{1}{turnsratio})^2$, where the turn's ratio is greater than 1 again, whenever I am transferring it to the higher voltage side, I have to always multiply by a factor, which is greater than 1 whole square. So, if I am looking at $\frac{220}{110}$ V. 220 is going to carry a lower current, if it is carrying lower current, the impedance has to be larger.

So higher voltage side will always manifest larger impedance and lower voltage side will always manifest, you know it is going to essentially show lower, higher current because of which it will manifest lower impedance. So you are going to have high-voltage, high impedance, low voltage, lower impedance, that is the manifestation, all this confusions will be eliminated if you are doing per unit, because if I look at it here, in terms of per unit per unit impedance we said base impedance in this particular case on 220 V side was 22 Ω, whereas base impedance in this case was 5.5 Ω.

So if I express $(1+j3)$ this is what is $\frac{(R_1+jX_1)}{22}$, this is what is the per unit impedance of the primary and here I am going to have $\frac{0.26+j0.8}{5.5}$ is going to be the per unit impedance of secondary. Now you calculate the per unit, if you guys have the calculator, please try to calculate the per unit, both of them should be almost comparable, I am not saying there will be exactly equal, but they will be comparable.

Student: (()) (17:28)

Professor: They will not be equal, in fact ideal transformer everything should to be 0, ideal transformer everything should be 0 and only the parallel parameter should be infinity, I reiterated, ideal transformer, so if I am going to have an ideal transformer winding resistance of 0, leakages are 0, magnetizing reactants is infinity and core loss components of resistance is infinity, actual transformer generally I am going to have the primary and secondary impedances comparable, I am not saying exactly equal, they are comparable.

So when I write it in per unit, if I try to write this in per unit, this is $\frac{1}{22}$ that is $\frac{3}{22}$, whereas this will be $\frac{0.26}{5.5}$, I can multiply both of them by 10 and multiply by 4, then I will be able to get essentially the same base 22 Ω, so 0.26×4 will be close to 1 again. So, I can say very clearly that the impedances what I have got, although I have calculated independently maybe they would be comparable.

So just by observing the values you would be able to say whether you have made any mistake in the calculation or measurement, if for one of them I get 1 Ω, for the other thing 1 p.u, for the other one if am getting 22 p.u for example. So, the per unit value give you some kind of estimate, so looking at them, you would be able to say whether you have done all the calculations correctly.

If I look at a transformer, normally the voltage regulation has to be less than 10 percent, in most of the cases. So voltage regulation at the end of what we are calculating is on a per unit basis because we are dividing it by rated voltage all the time, so we get the drop and we are dividing it by rated voltage because we do that again, we are able to get an estimate whether the voltage drop is less than 10 percent, that means whether I have done everything correctly or whether the transformer is good enough, all these things I would be able to get a feel for right by observing, that is one of the major advantages of using per unit notation.

So, generally whenever we buy a transformer from the industry, they will only say the impedances so much percentage, that is may be 0.1 p.u or 10 percent, this is what they will see. So what we mean by this is $\frac{I_{rated} \times Z_{eq}}{V_{rated}}$, only thing you have to make sure is I_{rated} and V_{rated}, I take it completely on the LV side or completely on the HV side.

Similarly, I take Z_{eq} also from completely from the LV side or completely from the HV side, I better take everything from one side, this is equal to 0.1 that is what it means, the meaning of this means if I know this $220/110\,V$ transformer 2.2 kVA, when it is carrying a current of 10 A on the primary side, I am looking at what is the drop in the Z_{eq}, visualized from the primary side and I say that that drop as compared to 220 V is 10 percent. So, I am going to have this entire thing equal to 22 V, if I am trying to look at it from the primary side, when V rated is 220 V.

So this is the meaning of the per unit basically and most of the industries mention the R_C values, X_M values and R_1 and $R_2^{'}$ together as R_{eq} and X_1 plus $X_2^{'}$ as X_{eq} all of them are mentioned in per unit, hardly ever mentioned in ohmic values because if you try to look at the ohmic values, especially for a transformer like 400 V/ 4000V or 40,000 V, you will see the ohmic values grossly mismatching between the primary and secondary, because it is same kVA, the current would also be stepped up by 100 fold on the primary side and the voltage is stepped up by 100 fold on the secondary side.

So, if you look at the ohmic values on one side, if it is 1 Ω on the other side, it will be 10,000 Ω. So it will lead to a lot of discrepancy and it may be very difficult for you for anybody to understand whether things have be done properly or not, when you express it in per unit all of them will boiled down to same percentage roughly because you are using the base voltage as that particular side voltage and current as that particular side current.

So in general per unit gives two advantages, one is just by observing the values you can say whether the values kind of fall within the normal range for a transformer, for an induction motor, for a synchronous machine, you should be able to say that because all of us generally, who are familiar with electrical apparatus can say transformer should have impedances less than 5 percent and similarly I should be able to say if it is R_C or X_m, it will be even more than 100 percent, maybe you know 200, 300, 400 percent very high values.

Whereas, if I look at an induction motor, I can say normally the impedances, series impedances will add up to 25 to 30 percent. So roughly we have the ranges for different machines, so by just observing we would be able to say whether the ranges are falling or the values are falling within the range, that is the first advantage, second advantage is you can just calculate the values from either of the side, no problem, you do not have to transfer 1 ohmic values from one side to another, everything that will be given will be normally in percentage, which will be common for the entire apparatus, whether you look at it from the primary or secondary, so that is the major advantage of per unit.

One of the problems in the tutorial sheet, I think had given percentage impedance is 10 percentage or something like that, which actually indicates this, $\frac{I_{rated} \times Z_{eq}}{V_{rated}}$ for any side, whichever side it is 0.1 that is what it means. So similarly, I should be able to say $\text{Percentage Resistance} = \frac{I_{rated}^2 \times R_{eq}}{kVA}$.

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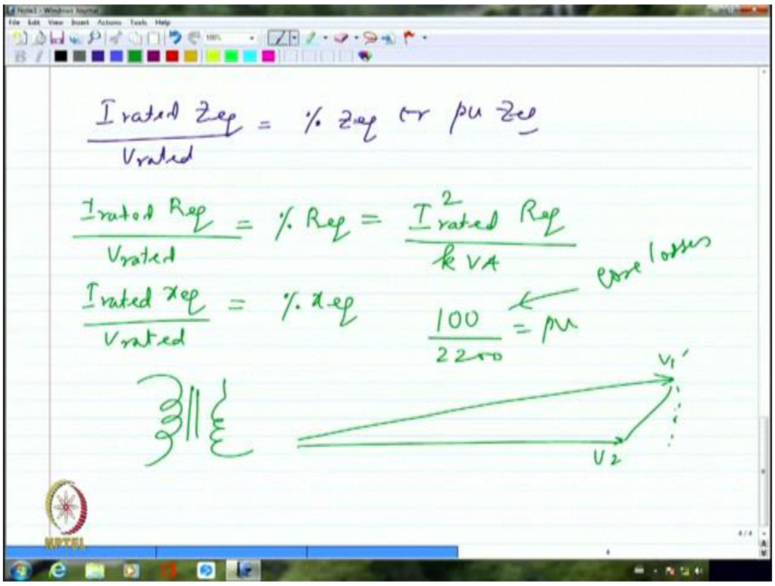

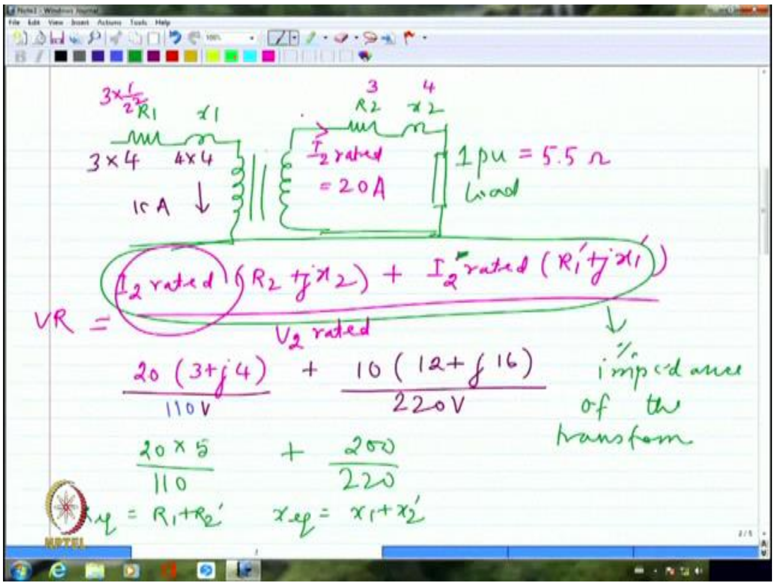

See we wrote $\frac{I_{Rated} \times Z_{eq}}{V_{Rated}} = \%Z_{eq} = Z_{eq}(p.u)$, I can similarly write, $\frac{I_{Rated} \times R_{eq}}{V_{Rated}} = \%R_{eq}$, instead I can multiply and divide by I_{rated}, so what I will get will be $\frac{I^2_{rated} \times R_{eq}}{kVA}$ basically because $V_{rated} \times Irated = kVA$. So, this also will give me per unit resistance. One of the problems gave this, at rated condition, the ohmic losses, where so much percentage of the overall kVA rating was given, the rated copper losses where 5 %, 2 % of the rated kVA, that means essentially R_{eq} is 2 %.

The same way I should be able to write $\frac{I_{Rated} \times X_{eq}}{V_{Rated}} = \%X_{eq}$. So, must so for the per unit notation, we use it all the time in the industries, so that is all about reason you guys should know definitely how per unit notation is used, what is the significance of it, why it is been commonly used all over the industry.

Student: Why should we combine primary and secondary parameters to one side.

Professor: See if I am calculating separately for the primary and separately for the secondary, if I am trying to write Kirchhoff's laws, how will I take that into consideration, what I have to do is to write two loop equations and step up or step down the voltages and currents every now and then, I wanted to actually mention the whole thing as one single electrical circuit, if it is possible, which will actually give me ease of calculation, that is the only reason why we are transferring over all the parameters to one single side, so that, I will be able to write 1

KVL equation 1 KCL equation and I would be able to calculate the whole thing, that is the only reason.

In per unit notation we can definitely right about the core losses, if at all core losses in this cases in this case is something like 100 W, I would say $\frac{100}{2200}$, whatever I calculate as per unit I can say this is the core losses in per unit, you can again do it in terms of kVA.

Student: Z_{eq} in p.u and voltage regulation in p.u are they same?

Professor: Per unit Z_{eq} and voltage regulation at unity power factor at 100 percent load. Yes, his observation was Z_{eq} in p.u and voltage regulation in p.u are they equal yes, they are equal provided, you calculate it at unity power factor, no, not unity power factor, will it be unity power factor because 1 and 0, not really unity power factor, at least 100 percent load is for sure, because you are looking at $(R_{eq} + jX_{eq})I$, whatever is the I value and you are not really considering the power factor angle there.

So we are assuming probably the power factor angle to be 0 but we are not neglecting the practical component what we talked about, if you may recall we drew the phasor diagram and we said this is V_2 and there is some additional like this and then we are getting this as V_1 dash and then we said this vertical components we are neglecting, remember that vertical component we should not neglect.

So it will give you more accurate regulation actually, I times Z equivalent what you are getting is a very accurate regulation at rated current at unity power factor that is what it is so in one sense you can say Z_{eq} is indirectly giving you the voltage regulation, but at rated current.

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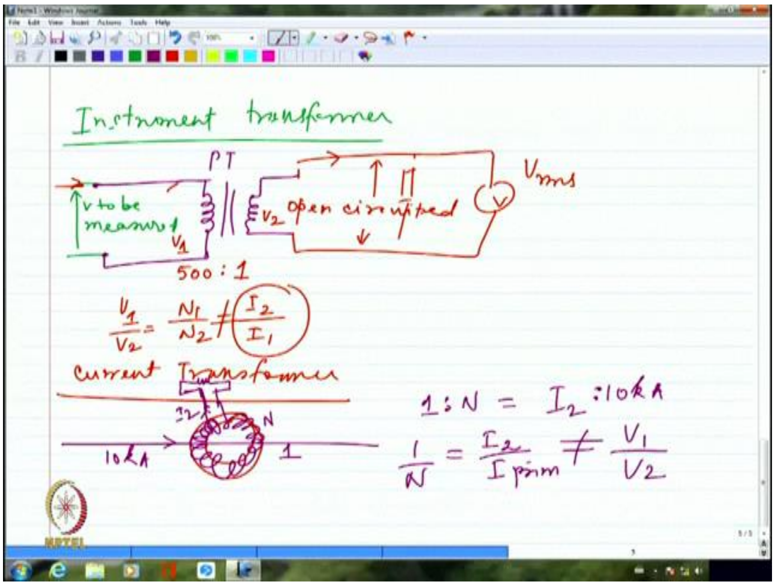

Before we venture into the three-phase transformer. Let us try to just take a quick look at current transformer and potential transformer that will complete our discussion on single phase transformers. So let us try to look at one of the special transformers which is known as instrument transformer, the name instrument transformer comes from the fact that this is being used for measurement and instrumentation, invariably measurement and instrumentation go hand-in-hand, because you may measure something, you may try to step up or step down, you may try to do some manipulation with it, and then you may try to ultimately see whether you know, you are able to follow whatever is the required pattern.

For example, you take an air conditioning system, maybe you want to have the temperature always fixed at 27°, so you might try to continuously measure what is the temperature, for that, you might have some kind of temperature sensor, that temperature sensor invariably will convert that into some voltage, because invariably most of our control system components are electrical in nature, so the temperature will be converted into an equivalent voltage.

Then that will be compared with our reference which is corresponding to 27° that will also be probably a voltage signal, so I will compare the two, if the temperature has not reached 27° as yet, it is at 30°, then probably I will have to turn ON the compressor within the conditioning system for quite a long time. So that compressor is going to be ON for maybe as long as it’s coolant is compressed and then it is expanded and then it goes through the heat exchanger and overall temperature comes down to 27°.

This is going to take place until the temperature reaches 27°, after it reaches 27° also continuously it is going to compare it. With the actual reference temperature. So if the compressor is off for too long, then again you might have to start the cooling cycle, so this instrumentation is done, maybe with the help of some of the apparatus called transducers, but we are not going to get into that, but we are essentially looking at if I have to control some voltage or current.

So voltage control if I have to do, I might have to measure the voltage, check it out whether it is as per what it need or what might motor needs, this if it has to be done in AC system, rather than in DC system, DC, you cannot use transformer obviously, but if I am looking at some AC system, where I have to measure thousands of kilovolts, I may not have a voltmeter to measure that kind of voltage so easily. So, what I am going to do is, let us say these are the two terminals across which I have to measure the voltage, so this is the V to be measured.

Now what I am going to do is to connect a potential transformer, I will call this as PT, potential transformer or voltage transformer and I am going to actually connect across these two terminals itself my potential transformer and the potential transformer should offer very large impedance, if it offers a small impedance, it will be as good as short-circuiting the two terminals to be across which I want to measure the voltage.

So this potential transformer should essentially works similar to a voltmeter. A voltmeter generally offers a very large impedance, so similarly should be the case as far as the potential transformer is concerned because of which the secondary of the potential transformer will always be open circuited, it cannot be short-circuited or it cannot be connected with a tangible, small value of resistance, no way, it should not be done, it should be always be open circuited normally and I may connect a voltmeter here at this end, I may connect a voltmeter, which will measure what is the RMS value.

What I am doing is to bring down the voltage from a very large value to a range where my voltmeter will work. So I may not have voltmeter available for hundreds of kilovolts, so I may have this as 1000:1 or 500:1 for example, as the range, so because of which if I am having 500 kV, I would be able to step it down as 1 kV and I would be able to measure this with the help of a voltmeter. So, I am essentially trying to use the services of the voltage ratio of a transformer, so that I am able to bring the voltage down to the range where my voltmeters would work.

But in the process I should not be drawing excessively large current from the supply, I cannot do that, that is the reason why I am keeping this as open circuit, keeping this as open circuit ensures that only whatever is the voltmeter impedance is transferred over to the other side, of course with the turn's ratio. So, it is going to be really, really a large impedance, it is as good as you are not drawing any current through the voltmeter or through the potential transformer.

So potential transformer will always have higher number of turn's towards the side from which I want to measure the voltage and much lower number of turns towards the other low voltage side and low voltage side invariably will be open circuited, it cannot be connected even with the smaller value of resistance. So in this case, if I write, if I may call this as V_1, if I make all this as V_2, I am going to have $\frac{V_1}{V_2} = \frac{N_1}{N_2}$, but I cannot write this is equal to $\frac{I_2}{I_1}$ because it is open circuited, I am not going to have any current on the secondary side literally.

Student: (()) (40:52)

Professor: Yes, impedance of the voltmeter generally will be of the order of kΩ or even more and that $k\Omega(\frac{N_1}{N_2})^2$ will be visualized by the source, whose voltage I measuring, which is fair enough, which is going to be really large that, see again large or small or relative, I hope you understand, how do I guess whether the impedance is large enough or not, that is where the per unit is very useful, if I say this potential transformer is going to be of 1 VA rating, but it is going to be 500 kV divided by whatever kilovolt it is, 1 kV.

Then I can definitely calculate what are all the base impedances. Compare to the base impedance, the voltmeter impedance has to be quite higher, then I am fine. See if I do not be open circuited, if I am going to connect a resistance here, okay, this will draw current, if this is drawing a current, this will also draw current, what I want to do is only to measure the voltage, I do not want to load the source, when I am drawing current I am loading the source, I may not, I do not want to do that, that is all I am trying to say, when you connect the voltmeter across your electrical circuit. You are just measuring the voltage, you do not want to a voltmeter as a load.

So, if you do not want to load it, you better not draw a tangible current, the current drawn should be as minimum as it can be. So, I am telling that it has to be as good as open circuit, that is all. So this voltage current relationship cannot be applied in a potential transformer because I am keeping the secondary side as open, the primary side will have no load current, secondary side has literally zero current, so under open circuit condition of any transformer $\frac{V_1}{V_2} = \frac{N_1}{N_2}$ is valid, but that is not equal to $\frac{I_2}{I_1}$. The other counterpart of this is, this is potential transformer, the next one is current transformer.

The current transformer is being used for measurement of current, high currents, so let us say, I am having a conductor through which may be 10 kA of current is flowing and I want to measure this current, it can be a variable current, the maximum is probably 10 kA, minimum can be as low as 100 A let us say.

Student: (()) (44:03)

Professor: I_1 is no load current, I_2 is 0 under open circuit condition, then how can I write the ratio, 0 by I_0, does not make much sense.

Student: (()) (44:16)

Professor: I_1 will not be 0, I_1 will be no load current, I hope you understand, open circuit condition of a transformer, you will have no load current, it will not be zero current. So, I cannot write this is 0 by 0, it is rather $\frac{0}{I_0}$, it is a no load current, so it does not make sense, that is why that relationship is not holding good specially when the transformer is under open circuit condition.

Let us look at the current transformer, so let us say I have 10 kilo ampere of current, it is a variable current, maybe it changes from 10 A to 10 kA and I want to measure this, for measuring this I can use this as the primary, very often current transformers use the conductor whose current needs to be measured itself as the primary, you do not have to have a separate primary at all, in all probability and what we normally do is, around this we put a toroid. Toroid is like a bangle around which I am going to wind many turns basically.

So that is also a laminated core which is like a bangle and then I am going to put huge number of turns around it, so in this toroid which is around the coil I am going to make huge number of turns, these are the two terminals that are available. Now this is essentially going to make the turns ratio and this is N, this is no turn at all, which is 1. one conductor means it is counted as one turn, so it is going to be 1/N = 10 kilo ampere, rather 10 kA is to the current to be measured, so let me call this as I_2.

Student: (())(46:35)

Professor: See this conductor is taken as one single conductor, which is actually equivalent to one turn, because return you do not know where it is and around that you are having a toroid which have N number of turns.

So obviously the current what I get here will be $\frac{1}{N}$ times, whatever is the current that is actually there in the conductor. So it will be clearly, you know step down, but here if I leave it as an open circuit, the voltage induced will be enormously high, so I can never leave the current transformer as an open circuit instead I should connect a small resistance, how small is small that depends upon again the per unit, if you calculate what is the base impedance, compared to base impedance make it really small.

So, I am going to have $\frac{1}{N} = \frac{I_2}{I_1}$ is that so? $\frac{I_2}{I_1}$ or $I_{primary}$, but that is not equal to $\frac{V_1}{V_2}$ because I am going to literally short-circuit the secondary, literally I am going to short-circuit the secondary because if I do not short-circuited, if I am having a 10 kA current, if I have even 1 V, it should be translated as maybe 1xN V, N may be 10,000, so I will get 10 kV any if I put my hand there by any chance I really had it, so we have to be really careful, because the insulation may not be able to withstand that kind of voltage.