Power System Dynamics
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Lecture - 17
Modeling of Excitation System (Contd….)

Friends, we shall study modeling of excitation systems.

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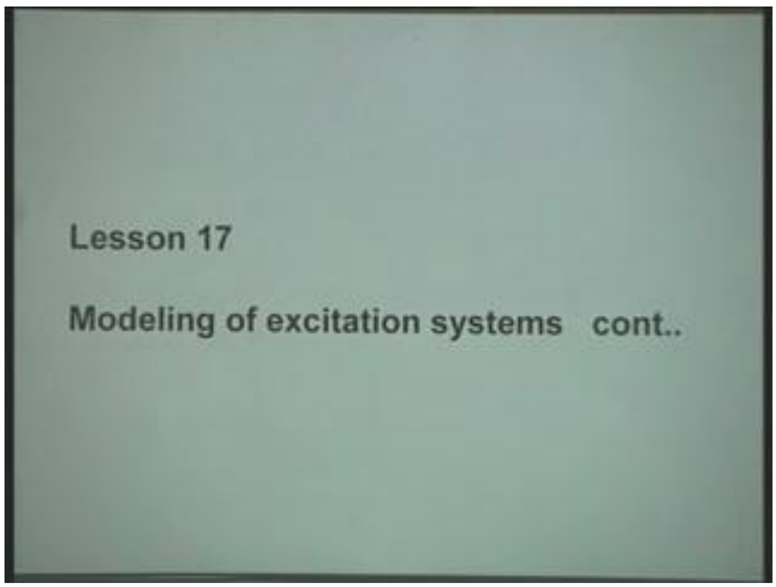

Last time we have discussed the modeling of DC exciters, AC exciters and today we will discuss the modeling of some more important comp1nts of the excitation system and then we will discuss a few typical excitation system models at the end. Now in any excitation system we have a regulator AC regulator and the output signal of the regulator is amplified right and for that we use amplifiers. The amplifiers may be electronic amplifiers may be magnetic amplifiers or rotating amplifiers right. Now these amplifiers, we will just see how these amplifiers are model a basic model of a amplifier whether it is rotating or whether it is electronic can be put in this form that is a amplifier can be presented by the gain constant K_A and a time constant T_A that is the transform function of the amplifier is K_A divided by 1 plus s times T_A.

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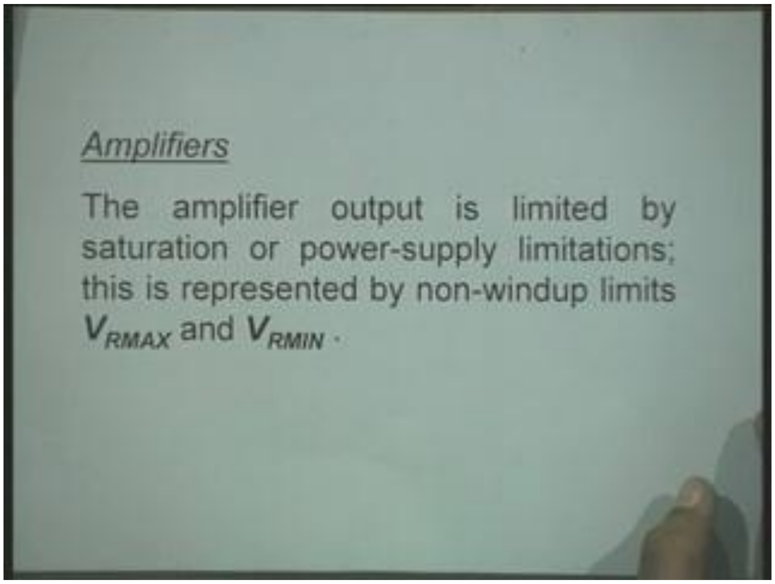

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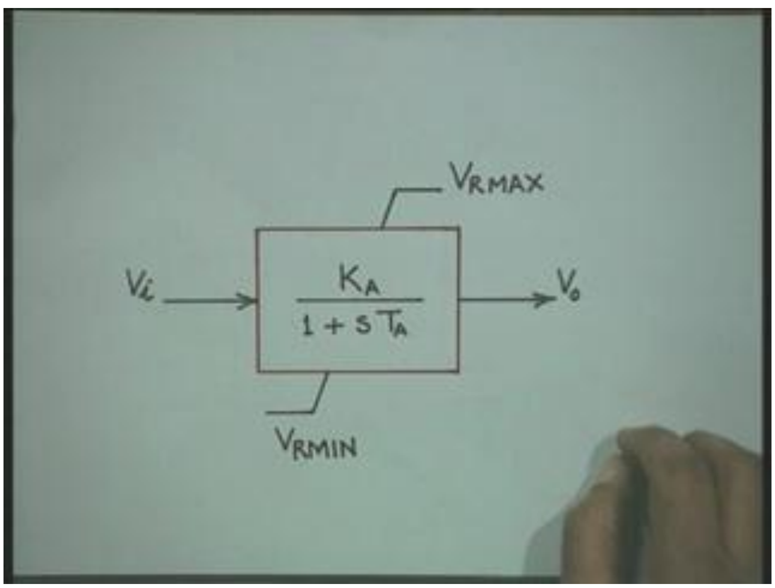

Now this amplifier will have the maximum and minimum limits that it respective what is the input signal coming the output will be limited to the maximum value because this V_{Rmax} and V_{Rmin}. For example, if you take the electronic amplifier okay there is always saturation and therefore the maximum value which is available will be determined by the characteristic of electronic amplifier.

Now these 2 time constants K_A and these 2 constants, the gain constant K_A and this time constant TA play very significant roll in the stability of the excitation system and therefore these parameters are required to be tuned. The next, the next important comp1nt of the excitation system is the excitation system stabilizer, the excitation system stabilizer is a closed is a closed loop system to stabilize the the performance of the exciter itself okay.

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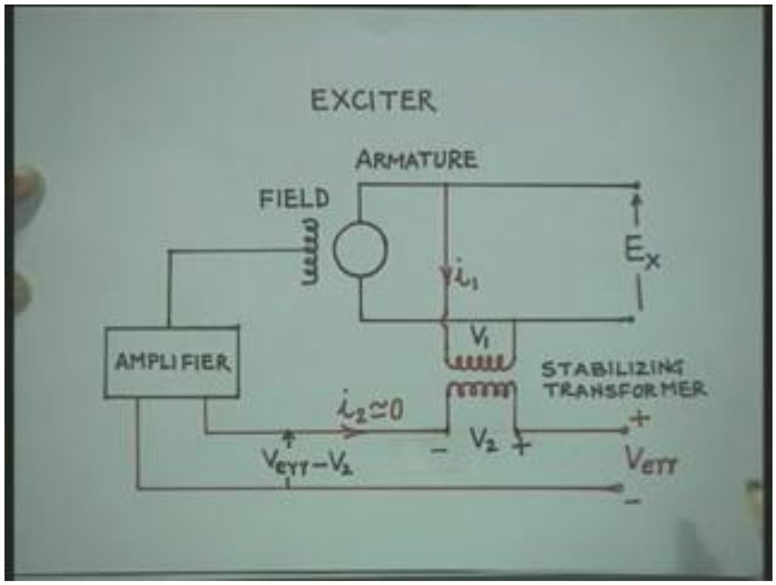

Therefore here, if I consider in general and exciter having its armature and field winding right the output of the exciter we represent as E_x. Now the this 1 simplest arrangement for stabilization which I have shown here is using a ah transformer that is you take a transformer and connect the primary of the transformer across the output of the exciter and the output of this transformer it is the secondary of this transformer is used to give a signal for stabilization.

Now here in this arrangement you can see here that this V error is the signal or error signal coming from the regulator that is from the summing point. In any regulator, we will have a summing point right and we get the error signal. Now to this error signal we separate this signal which is the output of the this transformer, okay you consider this transformer and this signal which you see here actually is V_{err} minus V_2 right. This signal is amplified and fed to the field winding of the exciter therefore here is a feedback loop.

Now this feedback loop is used for stabilizing the exciter this is called the exciter in system stabilizer right. Now we will just see something more about how this exciter system stabilizer is model that is we will develop a transformer function model of the exciter system stabilizer. Now to develop the transformer function model what we require is that what the transfer function is relating V_1 to V_2 that is V_1 is the input signal and V_2 is the output signal. We will relate this V_1 to V_2, now this can be d1 by writing the basic circuit equations that is you can assume actually that this is the primary of the transformer has resistance R_1 self-inductance L_1 and mutual inductance M.

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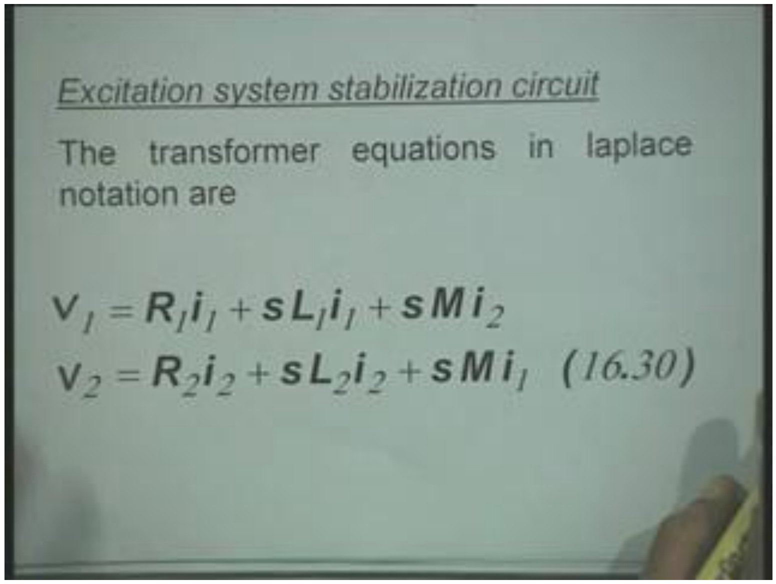

Okay, then the primary circuit equation can be written as V_1 equal R_1 i_1 plus sL_1 i_1 plus s times M i_2. Okay therefore here we are using this Laplace transform variable s, okay instead of d by dt okay therefore the basic equation is V_1 is equal to R_1 i_1 plus L_1 times d i_1 by dt plus M times d i_2 by dt right therefore, this derivative term we have replaced by Laplace transform operator s. The output voltage V_2 can be written as R_2 i_2, L_2 times d i_2 by dt this is again written as s times L_2 i_2 plus s times M into i_1. Okay they are the 2 basic equations which can be written for the next stabilizer transformer.

Now here 1 important thing which we have to observe is that the current i_2 which flows in the input of amplifier is very low any electronic amplifier or what is your type of amplifier we look for right their input impedances is very high and therefore the current i_2 is practically equal to 0 right. Now when we make this assumption that i_2 is 0, we substitute i_2 equal to 0 in these 2 equations right then our equations will reduce to this form, V_1 equal to R_1 plus s L_1 into i_1 V_2 equal to s M times i_1 that is in these 2 equations I am substituting i_2 equal to 0 right and therefore the transfer function relating V_2 to V_1 that is V_2 by V_1, V_2 by V_1 can be written as s M divided by R_1 plus times L_1 right now you divide both numerator and denominator by R_1 right then you will get the transfer function in the form sK_f plus divided by 1 plus s times T_f right where this constant K_f becomes M divided by R_1 this is M divided by R_1 and this time constant T_f will become L_1 divided by R_1 and therefore, we have a transfer function relating the output voltage this will be mistake I think there is a mistake here it is V_2 by V_1, V_2 by V_1 output to input transfer function to input V_2 by V_1 is equal to s times K_f divided 1 plus s times T_f right.

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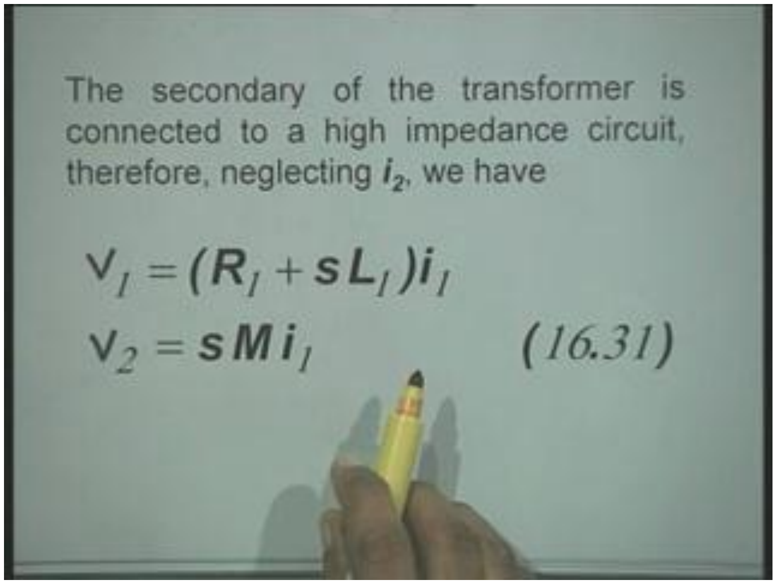

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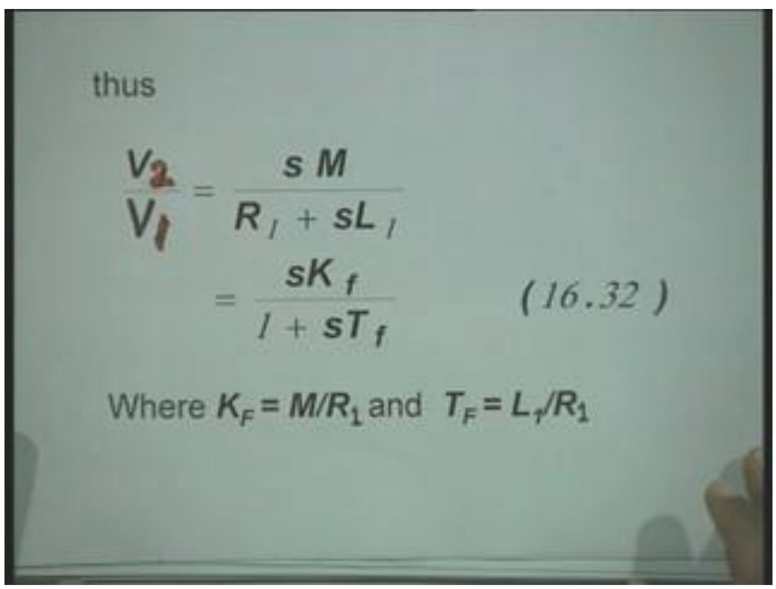

Now these 2 parameters again that is the gain constant K_f and this time constant T_f they are the important parameters, these parameters are also required to be tuned. Okay further you can see here actually that this is this represents derivative feedback, this represents a derivative feedback.

In fact in this arrangement, in this arrangement this transformer primary winding is designed to have high resistance so that when there is no variation of this output voltage, there is no variation of this output voltage right then there will be no output coming on the secondary of the transformer right. Therefore since this is the this is the DC voltage here right therefore as as long as there is fluctuation or variations are taking place in this output voltage there will be a corresponding feedback signal coming otherwise, the moment actually the we have steady state operation right then then there is some DC current flowing in this circuit and there will no output from this stabilizing transformer.

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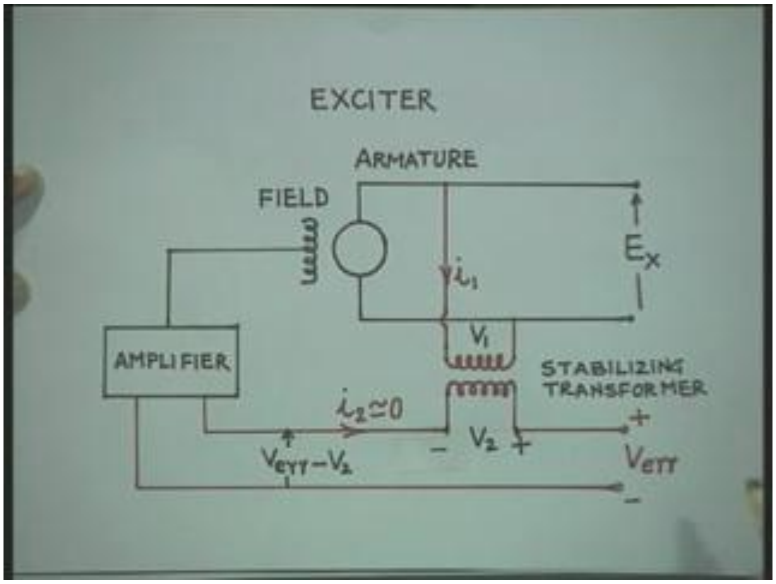

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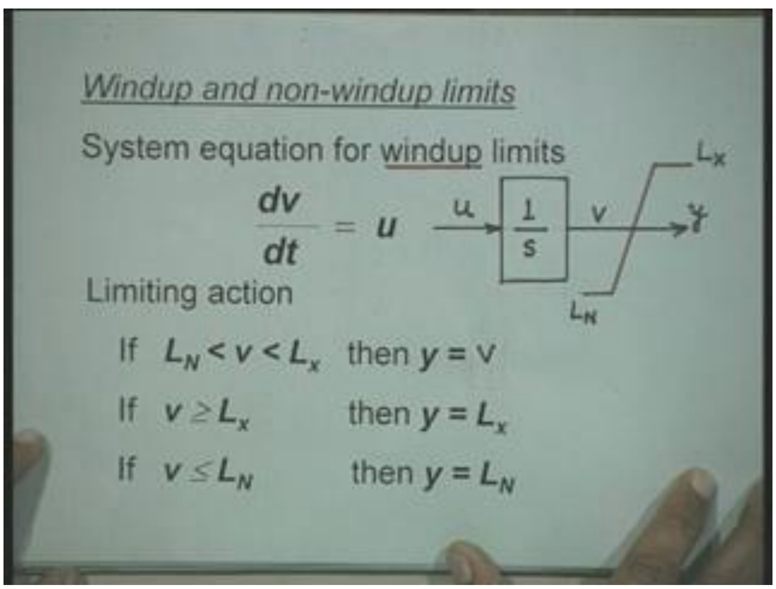

Now this is 1 arrangement which is used for realizing the derivative feedback although there may be alternative arrangements to achieve this derivative feedback. Now here, we will just briefly talk about the limits in the literature documented by IEEE standards or the IEEE standards. We define the 2 types of limits, 1 is called windup limits, another is called non windup limits. Now I will just distinguish between what we mean by the windup limits and non- windup limits in windup limits to illustrate this what we have taken is that we have consider an integrator a transfer function of an integrator. Now in the windup limit this is the transfer function of the integrator 1 by s, okay input signal is u output is v. Okay then we are putting actually the limiting functions L_X and L_N and the resulting output is y that is the output form this complete limiter is y while input is u right.

Now here in this arrangement when we look actually this transfer function model of this integrator then the we can write down equation dv by dt equal to u that is this transfer function basically represent this first order differential equation. Okay dv by dt equal to u right, now here in this arrangement in case this v that is the signal v which is coming here that is output of the integrator if v is greater than L_N and less than L_X that is it is in this range it is lying in the range between maximum and minimum then y is equal to v, this y is same as v.

In case this v the signal that is output of the integrator is greater than equal L_X then y is set equal to L_X. Okay that is this derivative this derivative of dv by dt equal to u this when it is solved okay if you get actually the signal v if it exceeds this upper limit L_X then the output will be set equal to L_X. This is very simple actually any system any system right the basic concept of the limiter is that if the signal is exceeding then we set it to the upper or lower limit.

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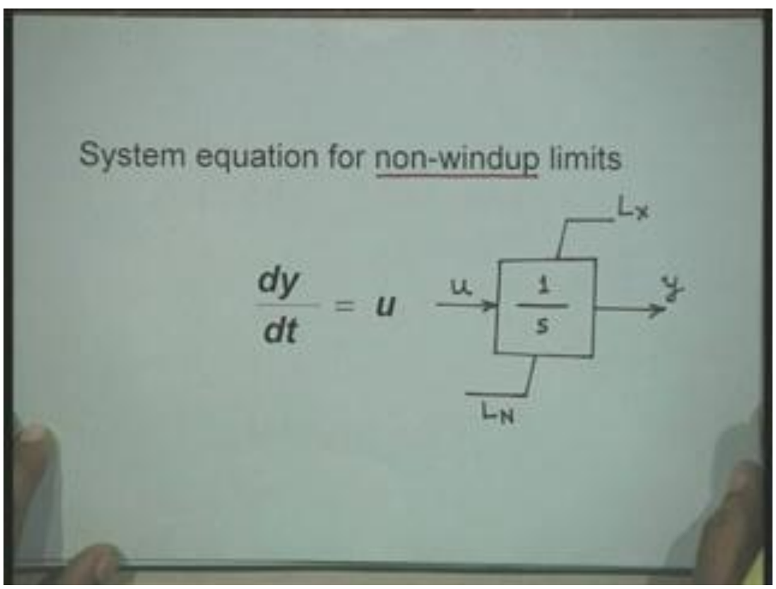

Similarly, if v is less than equal to L_N we set these 2 the lower limit L_N right. So that so that the they the device which is used actually to ah give output v or basically the output y right right, We will have this ah output confined to the upper and lower limit and when this output is less than this and greater than this the v is y is equal to v this is very simple this is called actually windup type limits. There are certain devices when they are used for limiting right then the integrator function of those devices can be represented by this model.

The another limit or another type of limit is called non windup limit, a non windup limit the the symbol which is used to represent a non- windup limit is we have this integrator transfer function 1 by s here. The input is u, output is y and instead of putting it outside this L_X and L_N that is we had put earlier here. Now they are put along with the block the idea here is basically that this output y, output y which is going to be produced produced will be confined between L_X and L_N right and this out output will never be equal to the what we have given actually in the previous equation that v, where the v was shown here right therefore there is a limit which is imposed by the device itself right.

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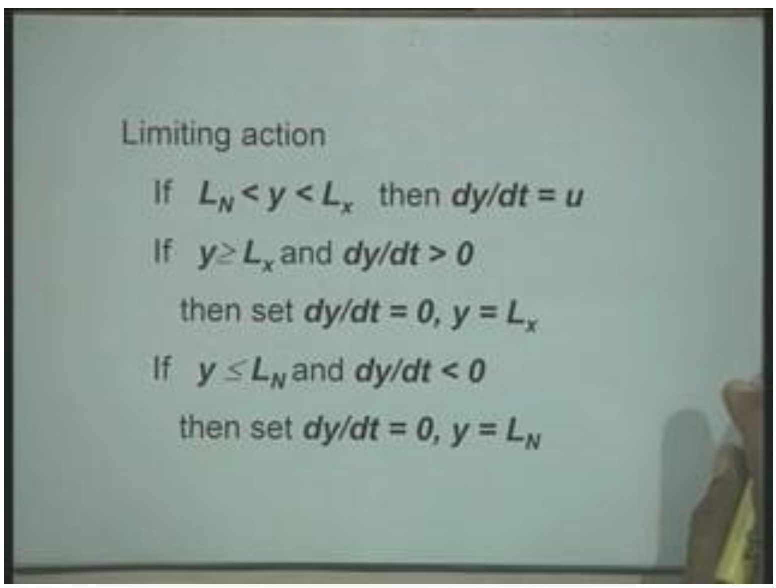

Now the equations which describe the this type of limit is that if y is greater than L_N or less than L_X then dy by dt is put to be equal to u that is in this function, if input signal that is the the you have the output signal y which is within the limits then dy by dt is put to be equal to u right in case this output is greater than L_X then dy by dt becomes 0 and and y equal to L_X.

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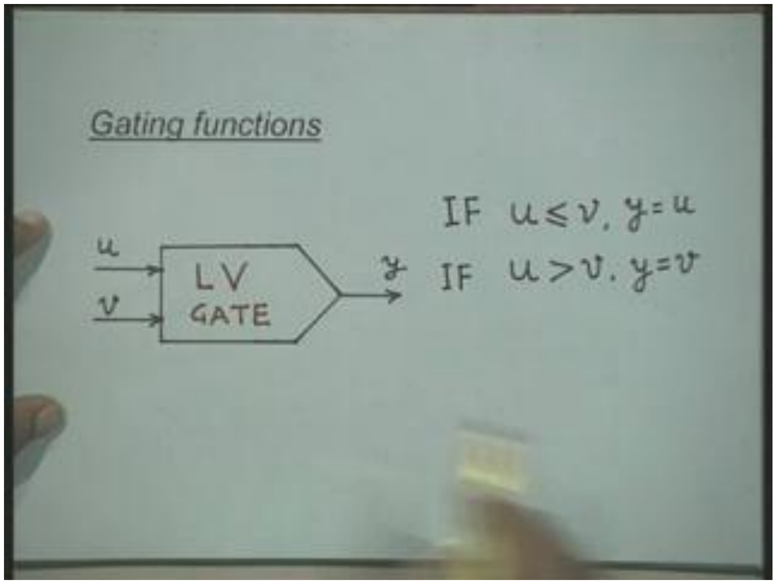

Similarly if y is less than equal L_N and dy by dt is less than 0, okay that is it is it is less as well as this quantity is less than negative then dy by dt again set to 0 and y is set equal L_N. This is the basic difference between the 2 types of limits that is the windup and non windup type limits therefore, when you lead the read this literature on excitation systems you will find that these 2 terms are frequently referred.

Now another next component of the excitation system model will be discussed now that is the low voltage gate and high voltage gate that is H_V gate and L_V gate. Now we have seen actually in our discussion on excitation systems, we have to incorporate the under excitation limit and over excitation limit. Therefore, basically this is a gate where we get we put 2 inputs u and v right the for for L_V gate, L_V gate the condition is that if v if v is less than equal to u right then y is equal to u that is out of the 2, suppose u is less than v then output will be equal to u.

Similarly, if u is greater than v output will be equal to v that is ah a very simple ah gate where we have 2 inputs 1 output the this gate will always ensure actually that output is equal to the smaller of the 2 inputs and the next type of gate is called H_V gate, H_V gate where input signals are again u and v output is y right. Now here if u is greater equal to v right, y equal to u it means the output is equal to the larger of the 2 signals, if u is less than v, less than v then output is y is equal to v because here v is greater v is bigger than u right. Therefore, these 2 gates are also required actually to model the complete excitation systems because we have to we have to implement the under excitation limit and over excitation limit and these limits are ah realized by using these H_V and L_V gates.

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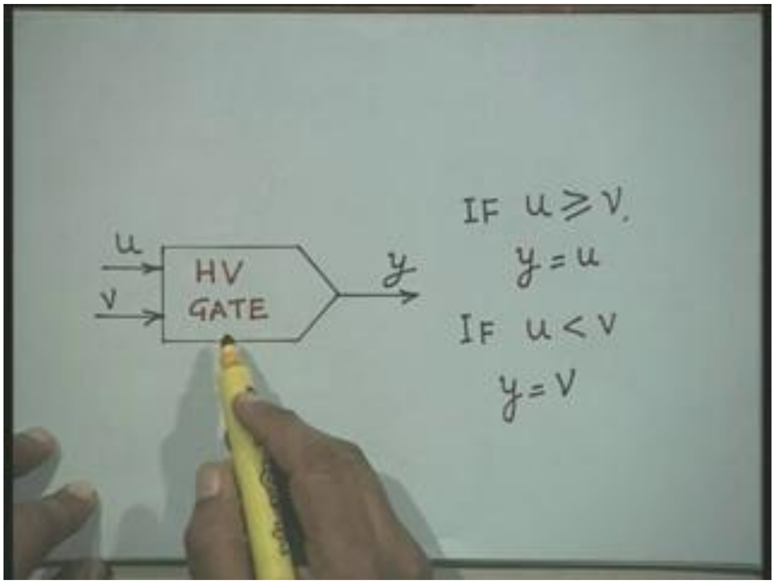

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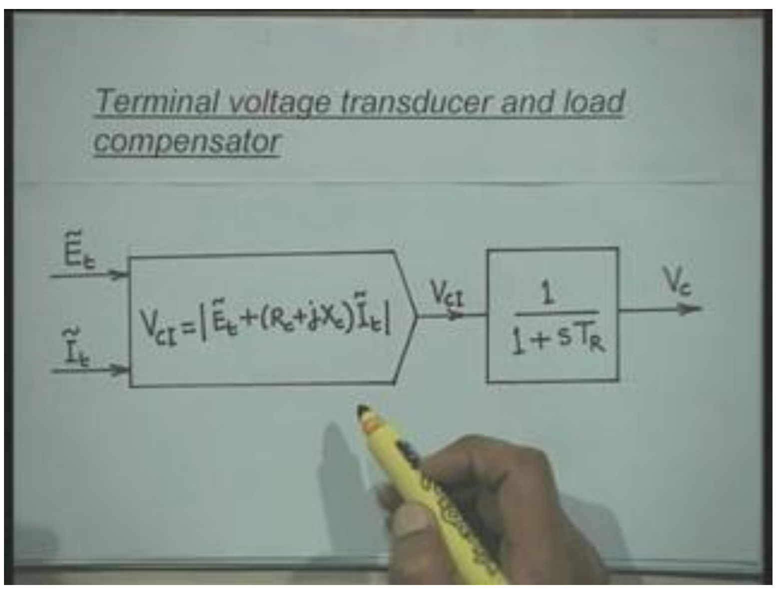

The next important component of excitation system is the terminal voltage transducer and load compensator, terminal voltage transducer and load compensator. We have discussed is our previous discussion the need for load compensator and the function performed by the load compensator. Now the this block is used to compute a voltage V_{CI}, V_{CI} which is derived by by adding a voltage drop R_c plus j time X_c into I_t to the terminal voltage E_t right and therefore, so far this block is concern input will be the terminal voltage a phasor quantity, I_t is the terminal current of the machine and these 2 quantities are processed here in this block and we get a signal V_{CI} which is a magnitude of this this signal E_t plus plus R_c plus j times X_c into I_t okay.

Now this signal V_{CI} okay is when it is processed right there will be some time delay in the processor and therefore this time delay is represented by this transfer function 1 they are by 1 plus s times T_R. Now this time constant T_R is generally very small in many cases of a many studies or many simulation studies, this time constant can be even neglected but its value is generally very small therefore we can say that the terminal voltage transducer and load compensator is having 2 blocks, the first processing block where we get a signal which is obtained by computing this expression and taking the magnitude of this expression and then it passes through the first order transfer function which represent the time delay of the transducer okay.

Now we have come to a stage where we will be in a position to discuss the complete model of the excitation systems. Now for discussing this complete model, let us let us again look into the ah models which were developed for DC exciter and AC exciters because I will be discussing only 3 models, 1 is known as DC1A model IEEE DC1A model another is IEEE AC1A model and third is IEEE ST1A model. In the IEEE, IEEE standard 1992 right it has large number of models, now the the substitutes which are put here I will just mention why these different substitutes are left that is DC1A that is initially when the first publication came they were called as DC exciters or DC IEEE DC model or IEEE DC exciter model, IEEE AC exciter model, IEEE ST or static excitation system model.

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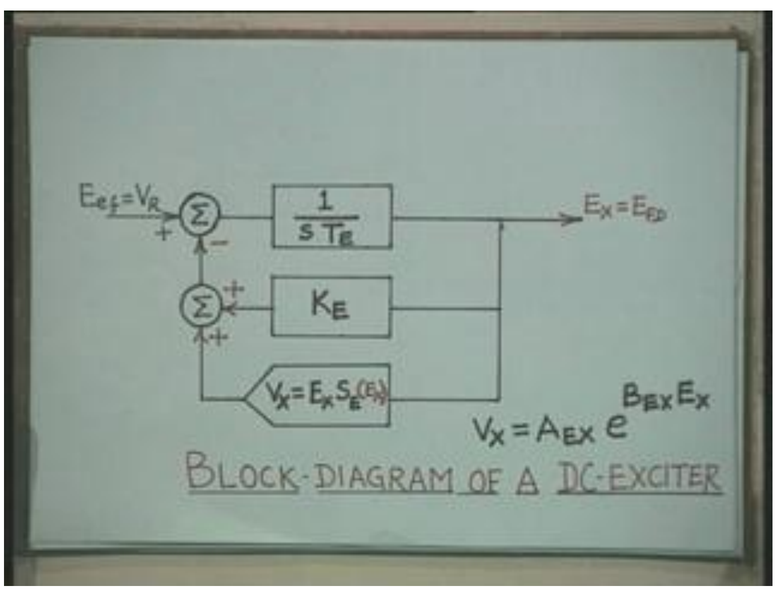

Then in 1981the IEEE gave another report where to distinguish this first generation model from the second generation model they put as subscript 1 they called DC1, AC1, AC2 like AC2 like that therefore 10 different models were given then in 1992 when they further revised right these models were added 1 more subscript that is DC1A that is A was added then somewhere in 1996 when another we can say report came where DCA was replaced by B. Therefore you will find actually in the last or the recent report they have used the symbols say DC1B or AC1B, B stands for that somewhere in 1990, we distinguish from the different models.

Now here since it is not possible to draw this model in totality on 1 sheet right therefore, what I have d_1 here to illustrate, we will take we will represent actually the various building blocks separately and these blocks will be assembled. Okay now if you look actually the DC exciter model then in this DC exciter model we can say that output is E_{FD} or E_X and input is the output of the regulator that is V_R that is E_{ef} equal to V_R therefore I will be representing this DC exciter model with the help of a block okay, by saying that input is V_R or output is E_{FD}. Okay therefore to draw all these things in the same sheet becomes very complicated and it is not possible to show in a small sheet.

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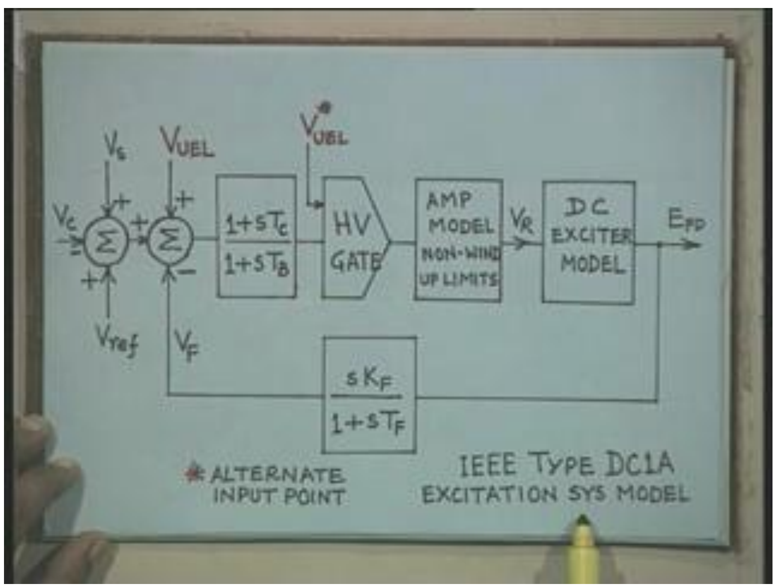

Now when you look at the complete model for the IEEE type DC1A excitation system that is the IEEE type DC1A excitation system is shown here. This block represent the DC exciter model which is now we have developed right which has saturation function which has 1 upon s time T and also the constant K right all these are part of this model, output is EFD and input is V_R. Then we have 1 model is called amplifier model that is we require the amplifier right therefore I am just showing the amplifier with non-windup limits that is here in this block diagram the amplifier is transfer function is K_A divided by 1 plus s times T_A with those V_{Rmax} and V_{Rmin} limits then input to this amplifier comes through an H_V gate, H_V gate and here here this H_V gate will get a signal from a transfer function this is normally called compensator that is that is for obtaining the desired performance of the D_C excitation system, we may add a compensator in the forward loop okay.

Therefore this is basically a compensator, okay. The output of this compensator is compared with the with the under excitation limit and we know actually that where this under excitation limit okay the output will be consider this this is realized using actual gate that is output will be corresponding to the higher of the 2 signals. So that we will realize actually that the the excitation system will not go below a certain limit prescribed that is the under excitation limit.

Now here I have put the star here to show that this under excitation limit can be realized by feeding the signal at the summing point also therefore there are 2 alternative ways of feeding this under excitation limit that is this signal if it is not required to be fed if it is fed somewhere right summing point. Okay then we can get rid of this H_V gate now the first summing point which I am shown here we have reference voltage the output V_c that is V_c is coming from terminal voltage transducer and load compensator and from the reference we are subtracting this V_c that is the output from the terminal voltage transducer and load compensator.

Okay then this V_s is the auxiliary signal which comes from power system stabilizer right therefore in this summing point. We have these 3 signals shown then the next summing point. We have put the derivative feedback is V_F is the output of the excitation system stabilizer okay and this V_F is subtracted from the signal which is the V reference minus V_c plus V_s and the under excision under excitation limit can be injected here itself right therefore, there are 2 alternative ways of realizing the under excitation limit Now this this read feedback transfer function is what we have derived earlier the s times K upon 1 plus s times T_F okay.

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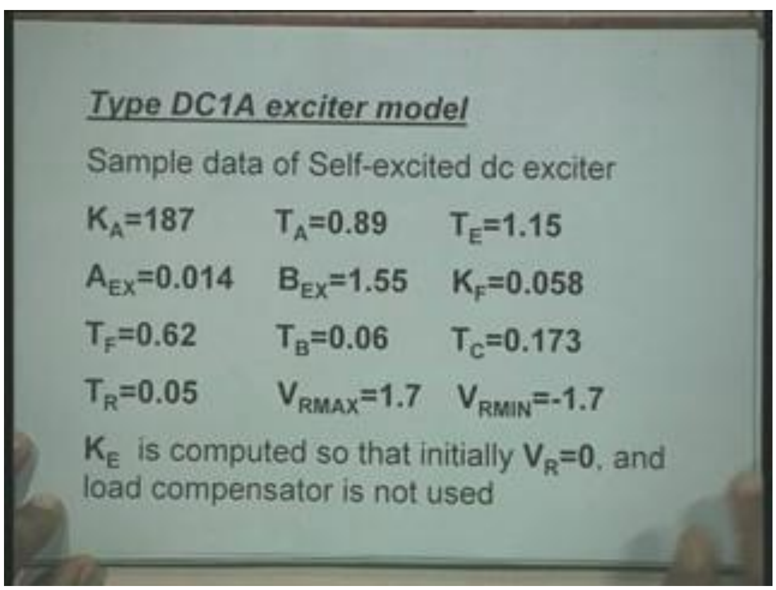

Now this transfer function model represents the both both self-excited, exciter self-excited DC exciter and separately excited DC exciter. The only difference is in the in the parameters of the model particular the K_e right. Now here one interesting thing which is d1 here is that when we have a self-excited DC exciter, we set the parameters in such a fashion so that we get the desired value of this field voltage with VR equal to 0, under steady state condition, steady state condition right the exciter ah field rheostat is set is such a fashion. So that the desired value of field voltage is obtained with with output from the regulator equal to 0 that is VR is equal to 0 with VR equal to 0. We should be in the position into get the required value of EFD.

The typical parameters of the DC1A exciter model are given below that is the parameters K_A is 187 T_A is .89, T_E is 1.15, A_{EX} equal .014, B_{EX} is 1.15, KF 0.058, TF 0.62, T_B .06, T_C .173, T_R 0.05 and V_{Rmax} 1.7 and V_{Rmin} 1. minus 1.7, the K_E is computed so that initially V_R equal to 0 and load compensator is not used that is R_C and X_C will be set equal to 0 when they are not using the load compensator R_C and X_C will be set equal to 0. Now if you see here actually then for this excitation system model we have large number of time constants gain settings right and the dynamic performance of this model is depends upon this time constants and when you design the excitation system right then these parameters have to be properly optimized or tuned.

So that we get a required dynamic performance this is a quite an important exercise which is to be done right at the design stage and when you install this excitation system the excitation system parameters are required to be tuned to achieve the required dynamic performance, I have talked about what we mean by the required dynamic performance of the excitation system, could you just tell me what are the required dynamic performance suppose I look from the point of view of say frequency response of the system what are the parameters which are set for right that is that is let me just mention here that the 3 parameters which we call is the gain margin, phase margin, bandwidth and overshoot right and the MP which was the overshoot that was to be 1.0 5 to 1. 15, phase margin should be greater than equal 40 degrees, similarly the gain margin should be greater than equal to 6 DB and it should have a high bandwidth, higher the bandwidth better will be the time response right. The next model we will discuss is the model for AC exciter.

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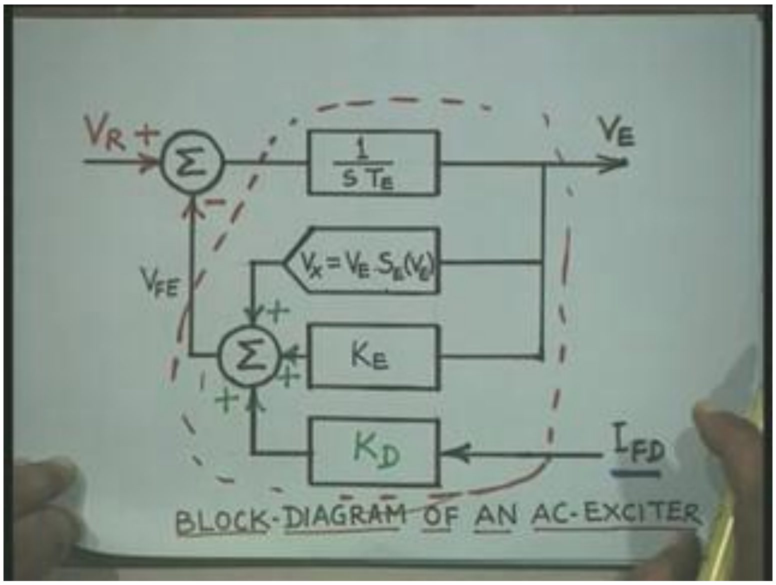

Now here, let us again look into the model of the AC exciter which we had developed earlier. The AC exciter model is similar to the DC exciter model except it has additional features there in this AC exciter model the demagnetizing effect of the load current is accounted by putting a constant KD and the field current IFD right this is 1 point, second is here output of this exciter is 1V_E V_E which will be further processed through the rectifier or will be rectified and we fed to the field winding of the synchronous machine right therefore, while modeling the complete AC excitation system I have represented this portion in the form of a block diagram I will say this portion when I just put from this portion this whole thing I {represin} ((00:36:54 min)) I am representing in the form of a block diagram that is you can see here the input is V_R 1 output is V_{FE}, I am showing this V_{FE} separately in the model V_E and input is I_{FD}. Okay now this to about the congestion on the same diagram, the another very important component of this AC excitation system model is the rectifier regulation model.

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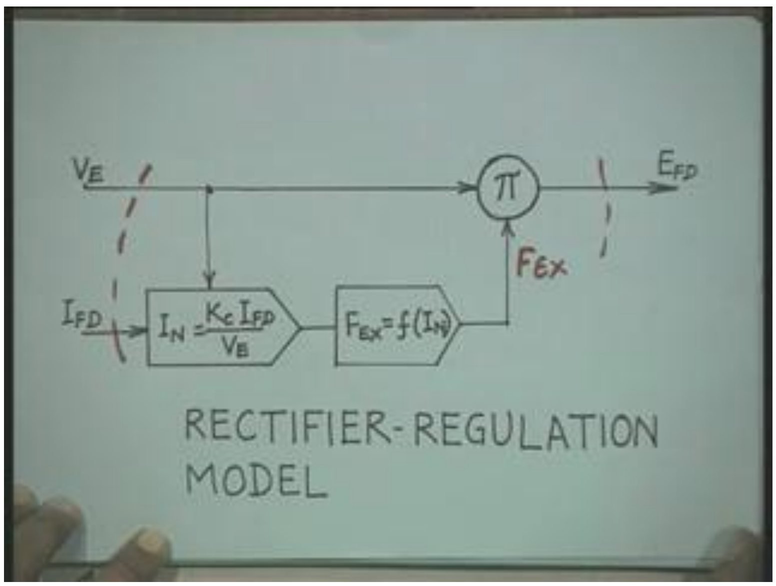

In this rectifier regulation model again input is V_E and field current I_{FD} the output is E_{FD} therefore, again I will be showing this as input output model showing this V_E as the input, I_{FD} as the input and E_{FD} as the output. This we have already seen actually that to to account for this rectifier voltage regulation the process is that we take the field voltage which is there which is flowing in the field winding of the synchronous generator. We take the output voltage of the A_C exciter these 2 quantities are fed into this block to compute a current I_N this I_N equal to K_C I_{FD} by V_E.

Now this constant K_C, K_C is function of commutating reactance, K_C is the function of commutating reactance. Okay then after computing this I_N we fed this to a non-linear transfer function that is F_{EX} equal to f of I_N and the output of this block that is F_{EX}, F_{EX} will be the out of this block right it is multiplied with V_E to get E_{FD} that is ultimately we can say that the as the loading of the exciter increases right or depending upon the loading right the the voltage which is the applied to the field wining of synchronous generator and the voltage which is produced at the terminal of A_C exciter they vary and this variation is determined by this multiplying factor F_{EX} that is F_{EX} into V_E equal to E_{FD}. Okay therefore so far this model is concerned I have shown as input as V_E and I_{FD} and output E_{FD}.

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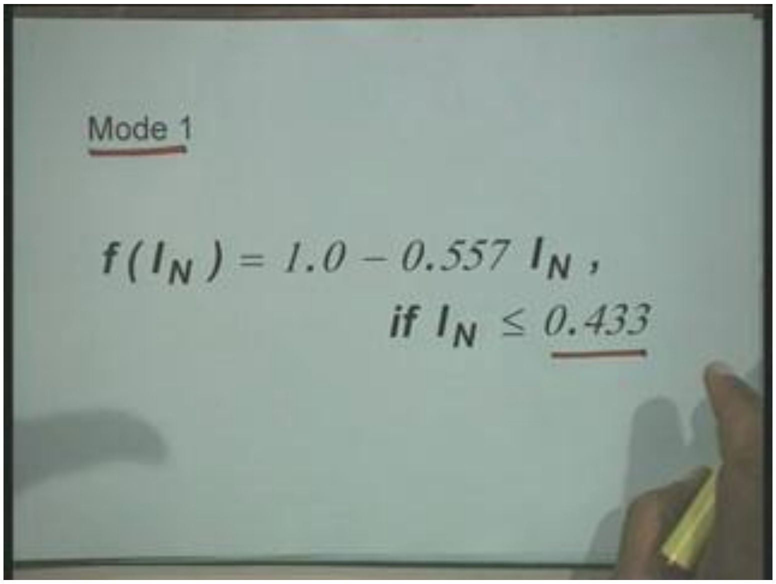

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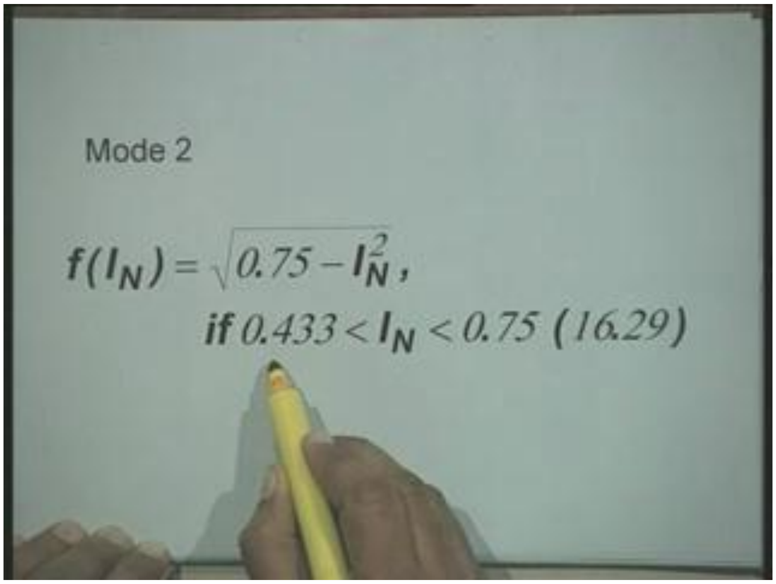

We had also seen that then when the rectifier operates in different modes, different modes the function fn is defined as I function of IN that is this function is the function of I_N is defined as mode 1 operation, 1 minus 0.557 into IN if IN is less than equal to 0.433 that is this 3 phase bridge type rectifier right is model model right. So that we identify 3 different modes of operation mode 1 mode 2 mode 3 right and in mode 1 the IFD is such that or the field current I_{FD} is such that the I_N which is computed quantity is less than equal to 0.433 right and this is the mode 1 operation. Similarly in the mode 2 operation the this non-linear function is square root of 0.75 minus I_N square where, I_N is in the limit .433 and .75 okay.

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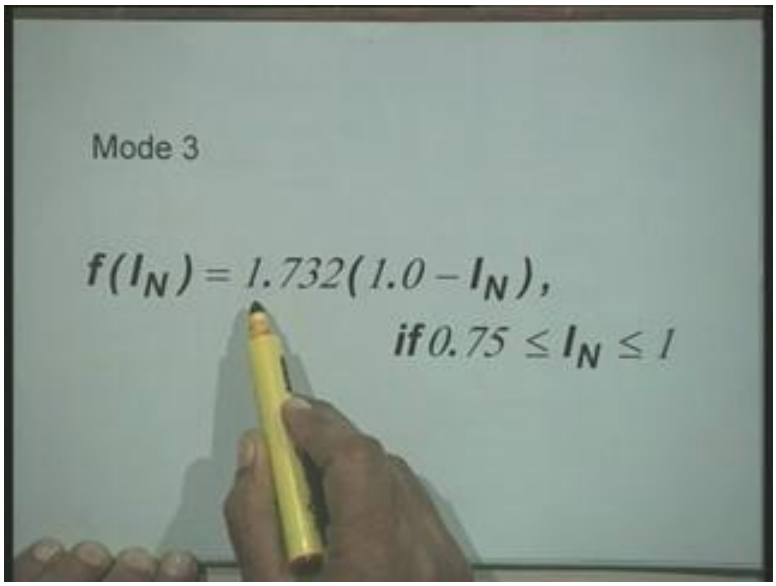

In the mode 3 operation this this function f I_N equal to 1.732 into 1 minus I_N where I_N is greater than .75 greater than equal to .75 and less than equal to 1 right. Now I have given you the expression for computing this quantity I_N earlier okay. Now the as I told you that in AC excitation systems we have different possible arrangements the model which I will be discussing here that is AC1A model that is IEEE type AC1A model right.

This model represents the the brushless excitation system it represents the brushless excitation system. Now in the brushless excitation system we have rotating AC exciter armature, rotating non control rectifiers and the field system right. This is the rotating part and the the control is excised here by controlling controlling the field current of the AC exciter you will just see here actually that this is the AC exciter the field system is stationary okay and by having a control current in the field winding of the AC exciter we control the output of the brushless excitation system therefore the model which I am discussing here that is AC1A model right, it pertains to it pertains to the brushless excitation system.

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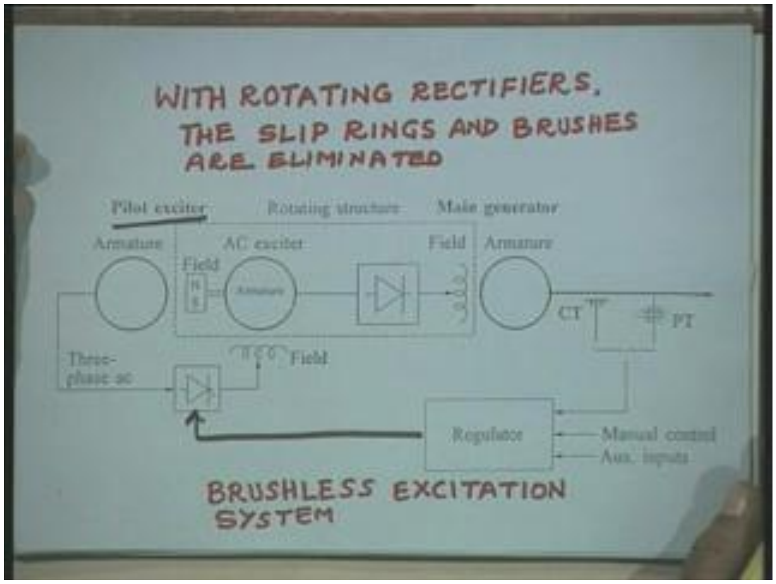

Similarly, there are other AC excitation system and the other models represent the other type of excitation systems because this variety of excitation system models have been given to take care of the different types of excitation systems right because from 1 excitation system to another excitation systems variations are there is it clear.

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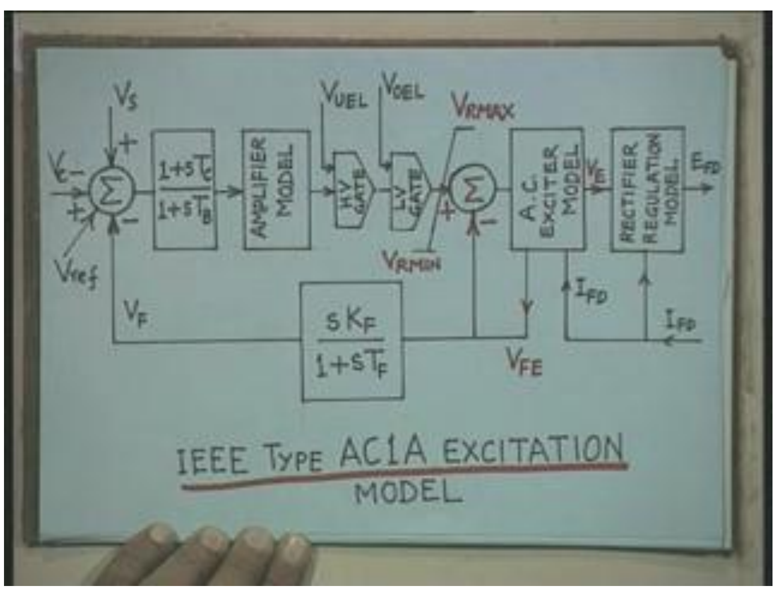

Now this block diagram gives you the complete model for the IEEE type AC1A excitation system, this is the IEEE type AC1A excitation system model. Now here you can start from the output side. Now this block diagram represents the rectifier regulation model rectifier regulation model. We have seen actually that rectifier regulation model input quantity was V_E and field current I_{FD} that is you have to sense the field current of the synchronous generator and this field current is fed to this and output is E_{FD}. Okay therefore when you want to draw the complete diagram if this block diagram can be replaced by the AC replaced by the rectifier regulation model, okay which had which had actually various components.

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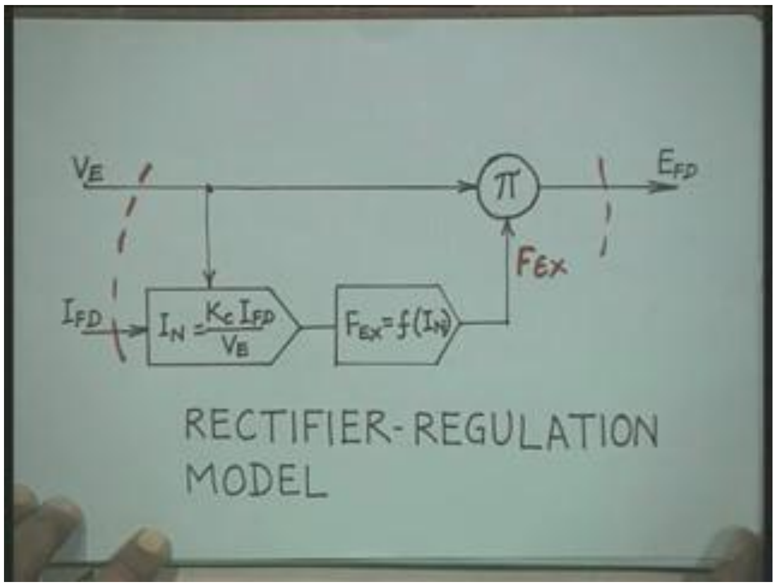

The components again let us see the comp1nts here were the computation of I_N and this non linear function right therefore basically you compute the value of I_N there will be logic function here. Okay and this will give you the output F_{EX} and ultimately you get the output E_{FD} right this is the rectifier regulation model. Then the next block is the AC exciter model I have shown actually that the output of the AC exciter model is V_E which is the terminal voltage of the exciter V_E the input were I_{FD}, I_{FD} and the the output from the regulator that is the V_R, V_R is the therefore here this summing block I have shown separately. Okay therefore in the summing block V_R is compared with V_{FE}, V_{FE} which is taken as output from AC exciter okay.

Okay, therefore the these 2 blocks can be represented by the detailed model to show the complete excitation system, this AC excitation system, AC1A model of the excitation system. Now the rest of these things we can start from the summing point V reference is always required any excitation system model the V reference is with the positive polarity V_C is with negative polarity that is the output of the terminal voltage transducer and load compensator. We add the stabilizing signal that is the auxiliary signal V_s the power systems stabilizer output signal V_s that we will show separately when we talk about power systems stabilizers and the excitation system stabilizer that is V_F this will come as a negative signal therefore here I have shown in the same summing block all the signals these are the reference voltage, the terminal voltage, the auxiliary signal that is the power systems stabilizer signal or there may be some other auxiliary signals also right and the excitation system stabilizer.

The excitation system stabilizer input here V_{FE}, V_{FE} while when you looked into the DC excitation system right the input to the excitation system ah stabilizer was E_{FD} that is the voltage is applied to the field winding state here but here since this is a non-linear function when there is nothing to be stabilized in this portion right because this relationship is a fixed relationship between the V_E and E_{FD} we have a fixed relationship right and therefore input signal is taken from the AC exciter that is V_{FE} which we had shown earlier.

This is again a compensator which may or may not be required right this is again for the purpose of proper stabilization of the whole thing then the amplifier model. We have H_V gate for realizing the under excitation limit U_{EL} H_V gate then the L_V gate to realize the over excitation limit. Okay and therefore this becomes the complete model of the field controlled rotating rectifier excitation system right. Here as I have told you actually that the control is exercised by controlling the field current of the exciter right. In case you have the stationary rectifier system stationary rectifier system then control is transferred from field circuit to the rectifier.

You can use control rectifier with different models have different different excitation systems will bee controlled in a different manner because in the in the case of a brushless excitation system since the rectifiers are rotating they are not accessible therefore control cannot be put on the rectifier therefore, they are non controlled rectifiers, the control is on the field circuit of the exciter.

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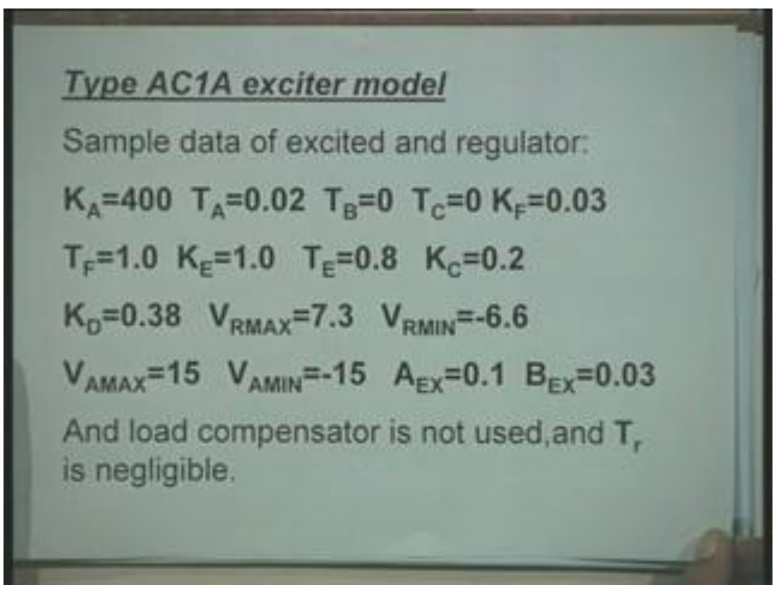

The last model, we will discuss will be the static excitation system but before I talk about the static excitation system the typical parameters of AC1A exciter model are given here K_A 400, T_A 0. 0 2, this in this particular case T_B and T_C are set to be 0 it means compensatory is not required. K_F is 0. 03, T_F is 1.0, K_E is 1, T_E is .8, K_C .2, what is this K_C? A parameter which is function of commutating reactance and it is required to take care of the rectifier regulation characteristic, K_D equal to 0.38 what it this K_D, K_D we have discussed number of time.

This is to take care of the armature reaction effect of the alternator that is AC exciter is an alternator right therefore K_D is 0.38 maximum minimum limits are 0. 7 .33 and 6.6 that is minus 6.6 6 that is minimum. V_{Amax} the output of the output of the amplifier can be 15 or minus 15 and the saturation function is modelled by A_{EX} equal to .1 and B_{EX} equal to .03 right again these parameters are required to be tuned actually and these are the typical tuned parameters of a particular system therefore this they are representative this should not be considered to be the optimized parameter that just representative to give some idea about the typical parameters of the excitation system.

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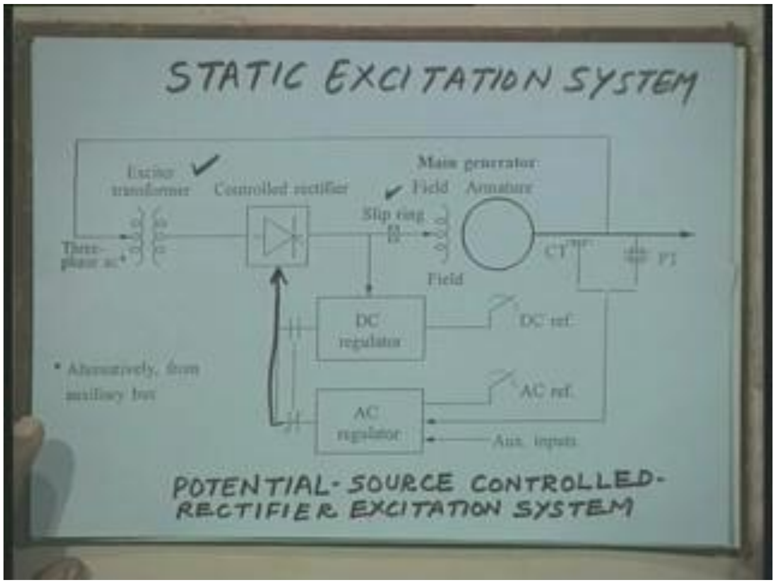

The last excitation system which we will talk about the static excitation system model, the static excitation system model here I will discuss the excitation system model with exciter transformer we have a controlled rectifier that is the excitation system power is derived through a exciter transformer this is a 3 phase transformer right and the output of this is rectified using controlled rectifier and fed to the field winding of the machine, of the synchronous machine through slip rings right and therefore our regulator acts on controlled rectifier that is AC regulator which gets inputs from current transformer po10tial transformer this will directly act on the control rectifier this is the very simple excitation system model time is over actually. I will just complete here of course I may have to complete afterwards some more portion time is little bit over actually right.

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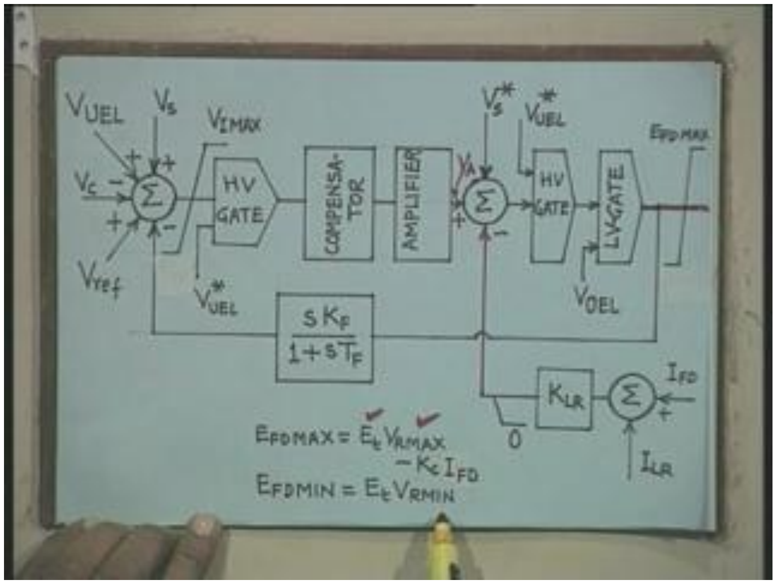

The the model looks like this the model ah looks like this it has all the functions similar the summing point is same your V reference, V_C under excitation limit stabilizing signal, the excitation system stabilizer right. This signal is called V_I this is the whole summation or V_I it is fed to H_V gate this is fed to H_V gate to realize the under excitation limit then there is a compensator which is put here again. Okay then amplifier and the output signal which comes here is V_S.

Now another one which is shown here is that the stabilizing signal can be put at this point as or add the summing point itself there are 2 alternative ways you can put the stabilizing signal here right and the this is fed to under excitation limiter then we have over excitation limiter and we get the output voltage from this. Now here this E_{FD} max is function of terminal voltage that is E_t V_{Rmax} and the K_C the constant depending upon the commutating reactance and I_{FD} that is this maximum voltage is function of terminal voltage because because the potential transformer takes its input from the terminal voltage itself right and minimum is E_t into V_{Rmin}. Okay it also has a field current under limiter field current limiter also is provided here right. This field current limiter it relays that you take this limiting value uh compared with the field current then you have some gain setting and fed here.

Now this completes the presentation of the different type of excitation system models and I suggest you to look into the IEEE standard which is published in 1992 right for further details about the excitation system models. Thank you!